THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

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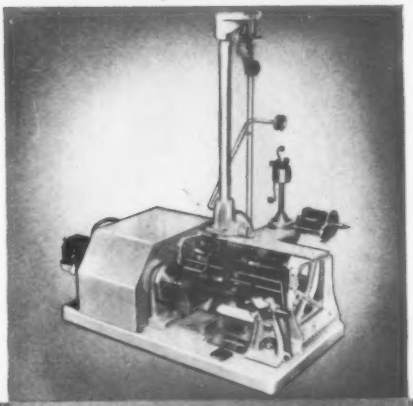

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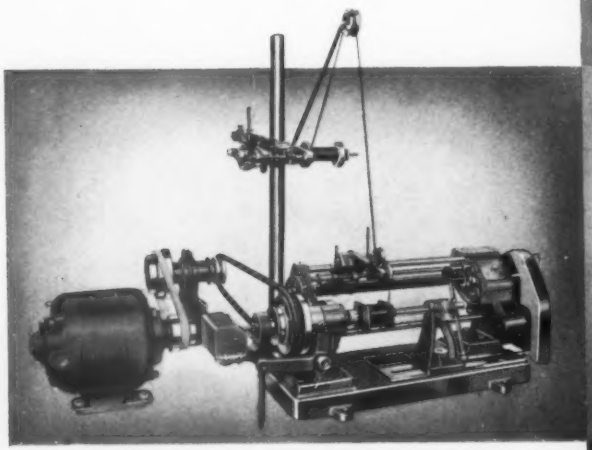

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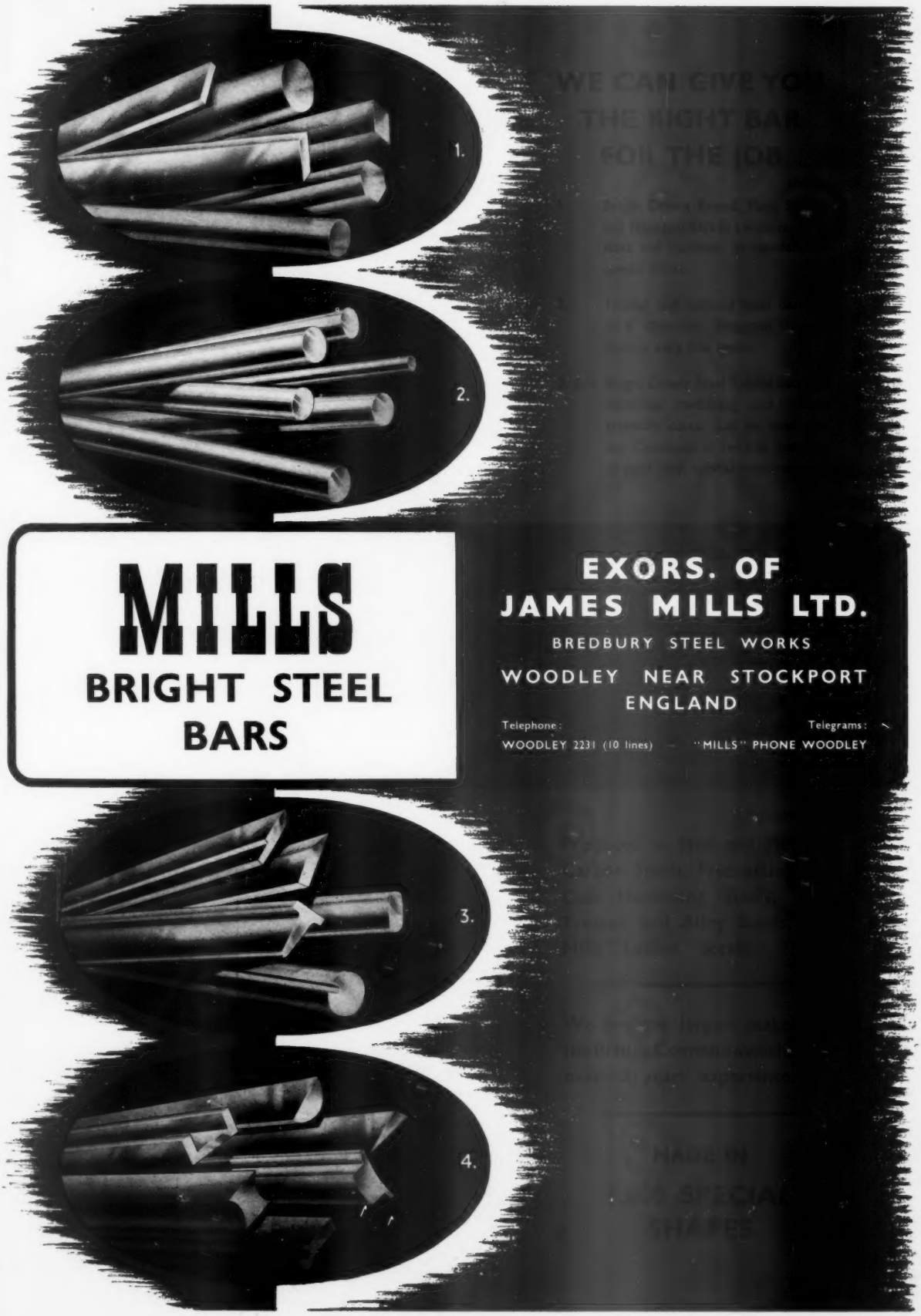
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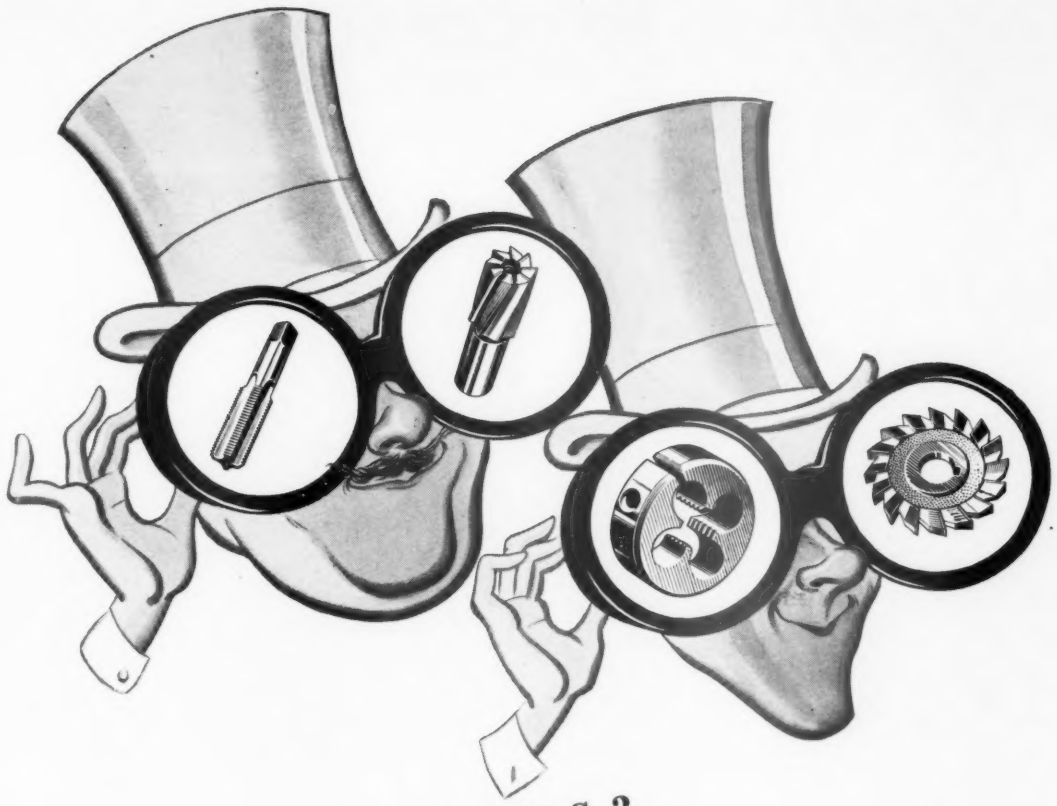

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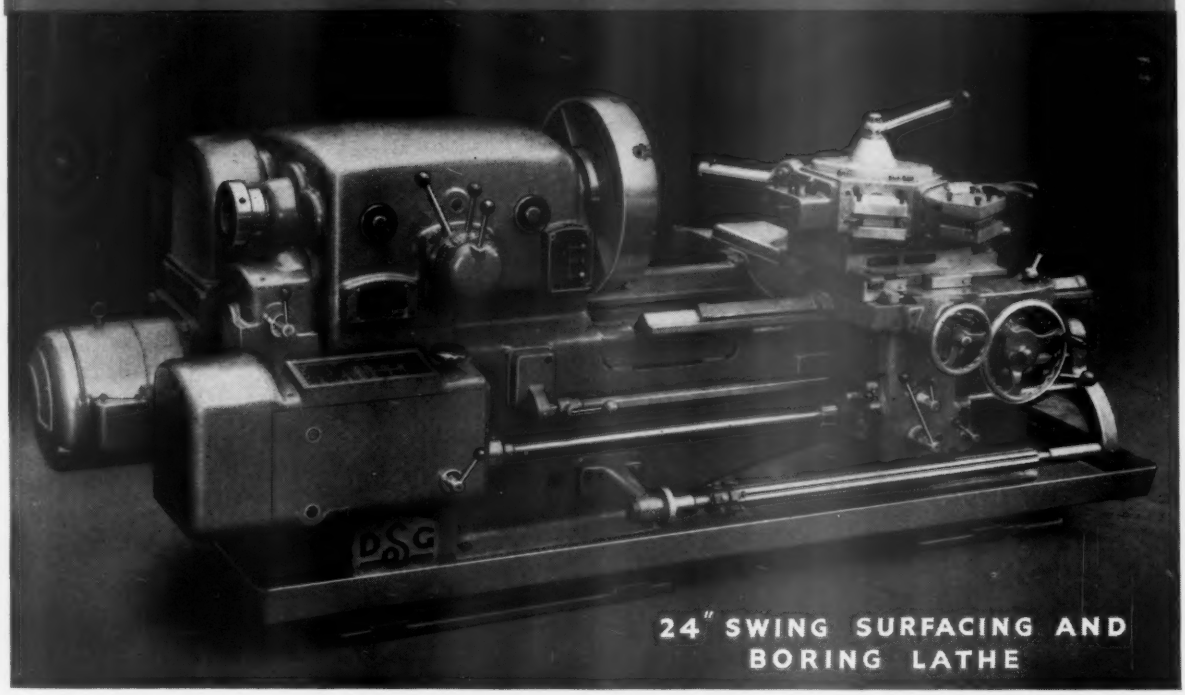

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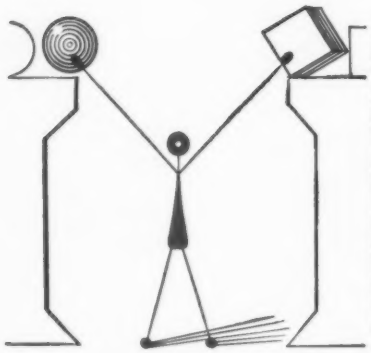
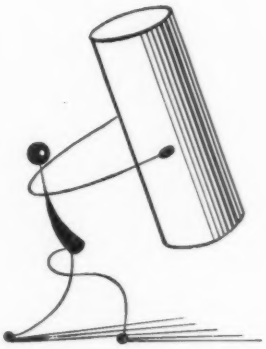
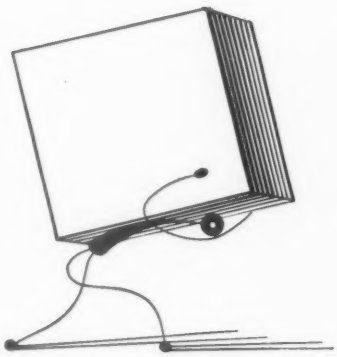


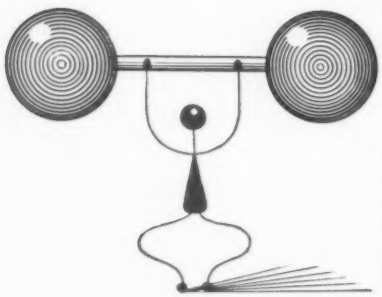
...reach...



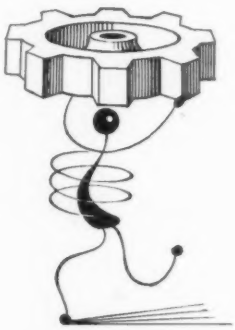
...grasp...



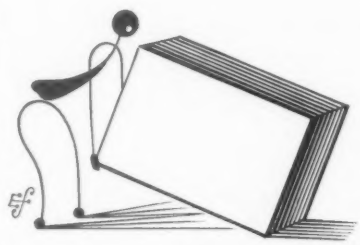
...carry...



...lift...



...turn...



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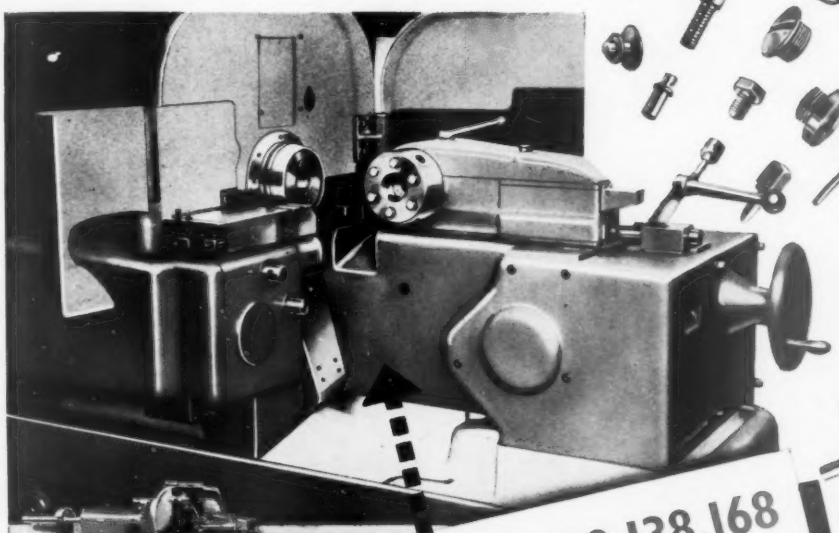

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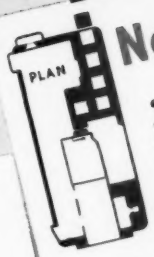

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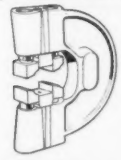

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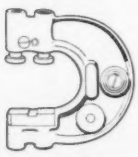

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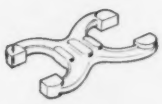

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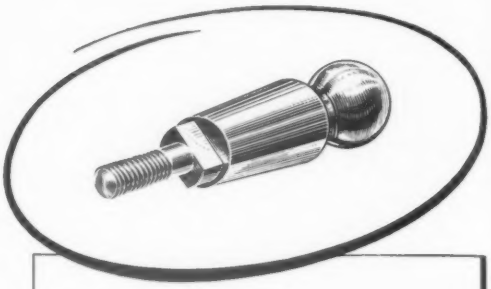

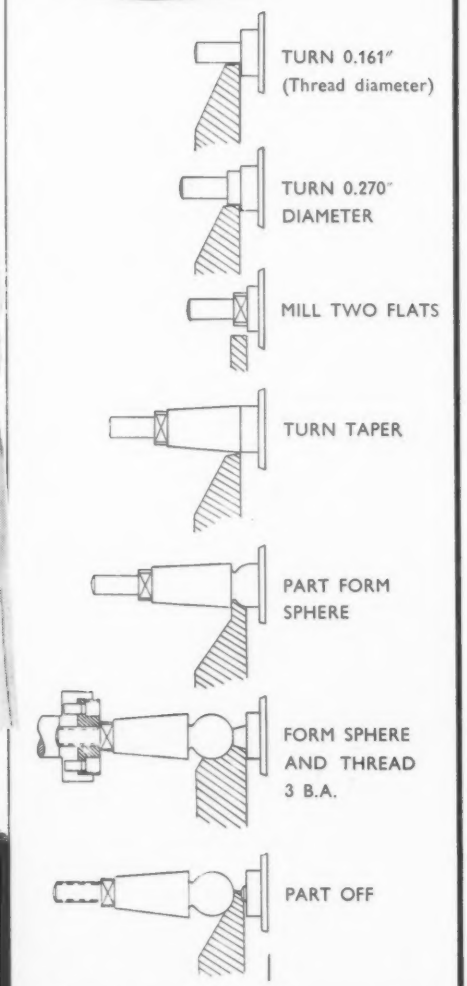

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The Institution of Production Engineers Journal
VOL. 33 NO. 10 OCTOBER, 1954

Education and Research for Production

Mr. M. Seaman, M.Sc., M.I.Mech.E., M.I.Prod.E.,
Chairman of the Editorial Committee, introduces a new series of leading articles.

Investment in Material - Investment in Men

IT is now a well accepted habit in the economic field to measure capital investment and to relate this to the measured annual increments of productivity. It has become clear over the years, by comparative studies, how important this investment is. Our investment in men, i.e. in training and research, has had its share of attention, but in view of the constant increase in demand, at almost geometric rates, for the higher technologists in all spheres, and particularly in production, it is probably worthwhile to examine this position in some detail. In the Institution's various proceedings attention has already been drawn to the work of Sir Ewart Smith, and recently to the proposals of Lord Halsbury in this field. In both cases, one in the general case of technological personnel, and in the other case, of production, management, and research personnel, attention was drawn to the degree of shortage, and to the need for further organisation to meet this shortage. We are concerned to examine these problems in more detail, and further such action as may be necessary.

Structure of Production and Industrial Engineering

In other countries, as has been underlined by recent reports, a conception of two functions (a) production engineering, and (b) industrial engineering, has grown up. There is need to examine the full meaning and content of these functions as there are very large areas of coincidence. It can be said, at the least, that in some other countries a very high level of educational organisation and research follow-up has been devoted to each of these specialisations; specialisation in this case being a doubtful word, as (a) production engineering, and (b) industrial engineering are largely the synthesis in one training curriculum of many types of specialisation.

Research Structure

In production engineering the two major components of production research are under the headings of (a) research associations under the general supervision of D.S.IR.; (b) research developments wholly controlled by individual Joint Stock Companies. There is no doubt that over the past 15 years there has been an acceleration of rate of progress and also direct impact on manufacturing from this type of organisation, and further efforts are being made to improve its overall effectiveness. Our daily work is concerned with contacts in this field, and its conversion into product and selling levels.

Education Structure

Whilst many full time schools exist specialising in production engineering and management at the Higher Technical College level, we have only the beginnings of well established undergraduate studies in the Universities. Many authorities feel that this structure must proceed along the lines of:

(a) establishment of full chairs in the principles of engineering production;

(b) the true development and selection of undergraduate schools in the Universities;

(c) development of first class research units in the Universities.

This would form the framework of training and development against which careers could be planned and built.

Action

Our review above raises many questions, and we feel that these topics would attract our highest authorities in leading the way and portraying the action we should take to our audience of engineers within the Institution. Subsequent leading articles will be devoted to these topics.

There is need for a clear study of the whole subject, and an explanation of just where we stand, and in detail, what are the possible lines on which we should proceed? So far, no full-scale examination of this problem has yet been made; the ball is tossed backwards and forwards between industrialists, educationalists, production engineers, and for lack of facts action cannot be said to be as incisive or as fully progressive as it ought to be. Let us therefore, as an Institution, promote something on the lines of a full-scale examination of this problem, say, at the level and standard of the Nuffield Fellowships, and based upon this work go forward with a strong policy.

DESIGN AND OPERATION OF OIL FIRED FURNACES

by J. M. AUSTIN, A.M.Inst.F.*

Presented to the Adelaide Section of the Institution, 24th February, 1953.

PERHAPS the title of my paper is a little misleading. I realise that Production Engineers are not concerned with how to design furnaces. Consequently, you will be pleased to learn that I have no intention of telling you. You are, I feel sure, interested in furnaces as an essential aid to efficient and economical production. It is with this point in mind that I propose to treat this subject. Just as with many other pieces of plant, there can be types and designs of furnaces to choose from. There is the right and wrong choice of furnace and the right and wrong way to use that furnace. I propose to deal with my subject in such a manner that you will have a greater appreciation of furnaces and their operation as an essential piece of your production plant, worthy of as much consideration as, say, machine tools, presses, forge hammers, etc., and will realise that the furnace is a very important factor in your production costs.

I need hardly remind you that we will only be concerned with oil-fired furnaces, as indicated in my title.

Our first important consideration is the proper application of the heat from the oil to the furnace and to the heating material. The improper application of the available heat in the oil is very often the cause of dissatisfaction at the design of the furnace.

In selecting a suitable furnace type, the question of material handling and furnace capacity and size are intimately bound up with the furnace arrangement. Furnaces can be classified into different types according to their interior arrangement for the transmission of the heat:

1. underfired
2. overfired
3. sidefired
4. direct fired
5. muffle

Underfired Type (Figs. 1, 2 & 3)

In this type, the combustion chamber is situated beneath the furnace heating chamber and the hot combustion gases pass up from the lower chamber through suitable ports into the heating chamber and, finally are taken through suitably located flues. There can be several variations of the arrangement as shown in the illustrations.

The first one is used for small furnaces such as tool hardening, up to, say, two feet hearth width, and its hearth is constructed in tiles.

The second has a side tile arrangement—usually of carborundum—and is used in heat treatment and annealing furnaces up to a hearth width of about four feet. In both these cases, the hearth is supported by side and centre piers of carborundum.

Fig. 3 shows the arrangement for large furnaces with a brick hearth supported by a brick arch construction.

The purpose of the underfired type is either:

(a) to protect the heated material from direct flame action and also reduce to oxidation by ensuring complete combustion of the fuel before striking the stock in cases of temperatures over about 750°C, or

(b) to obtain a low temperature with a fuel requiring a high temperature to maintain combustion, as is the case with oil.

Fuel consumption of an underfired furnace is sometimes higher than for an equivalent side or direct fired furnace. This is only because the heating capacity per sq. ft. of hearth area is less for the underfired type.

The advantages of the underfired furnace are threefold:

1. very complete combustion is obtained;
2. there is excellent temperature control;
3. there is good control of atmosphere.

The disadvantages of the underfired furnace are:

1. the hearth is exposed to heat from two sides. This limits the heating chamber temperature by the life of the refractory. For fireclay refractories this would be about 950 to 1000°C;

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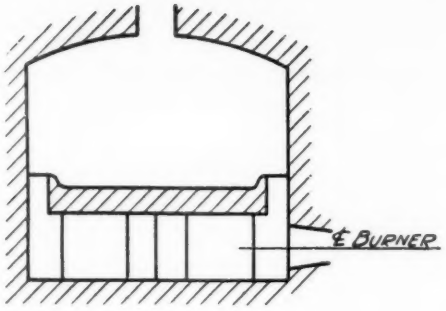


Fig. 1

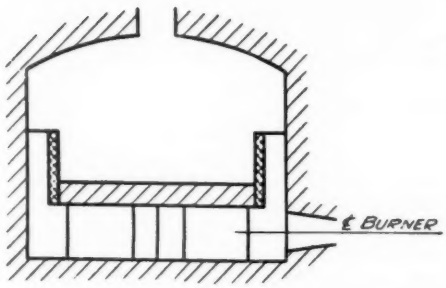


Fig. 2

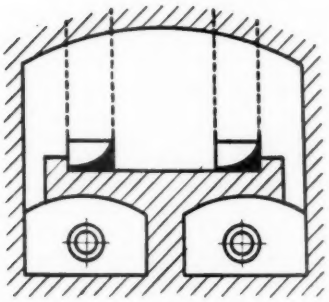


Fig. 3

2. the entire furnace load is borne by hearth and piers at considerable temperature, limiting the allowable load on tile hearths to about 70 lb./sq. ft.;
3. the arrangement is not adaptable to car-type and other moving hearth constructions.

Overfired Type (Fig. 4)

This construction has the combustion chamber situated *over* the heating chambers and separated by a perforated arch. The hot gases are forced into the heating chamber and thence removed by suitable flues situated at hearth level.

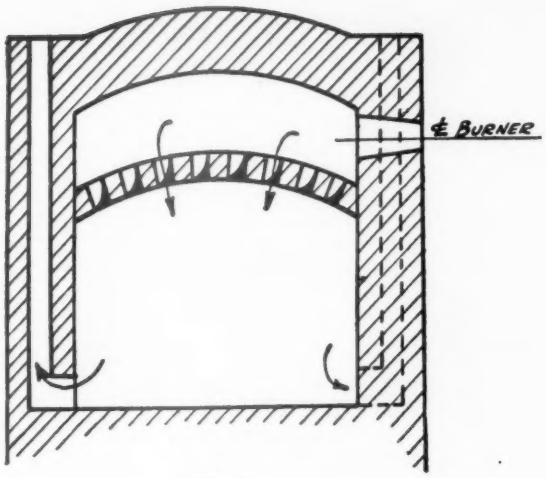


Fig. 4

The purpose of this design is exactly the same as the underfired, namely, avoidance of flame impingement, even heat distribution and minimum scaling.

The advantages are :

1. it is rather more efficient than the underfired furnace, because the gases *must* pass through the stock before leaving the flues;
2. it can be adapted to almost any form of furnace and is not seriously limited in its capacity to be forced.

The disadvantages are :

1. high cost of upkeep. The perforated arch is usually of special tiles and labour costs to renew it are high, for replacement becomes quite frequent at heating chamber temperatures above 850°C or where there is a lot of vibration.

   However, in spite of any advantages upkeep costs have prevented its use being at all general. I have only come across such an arrangement in about half a dozen cases, the most outstanding being a large pair furnace of some 3 tons per hour continuous operation.

Sidefired Type

This arrangement consists of a bridgewall between burners and heating chamber. This wall promotes ignition, by checking the velocity of the fuel from the burners to a point below the maximum speed of ignition and aids combustion by causing a turbulent condition, so that, when the gases pass over the wall, oil and air are intimately mixed. The heating material is also protected from fierce flame impingement. Fig. 5 shows the common arrangement for furnaces not exceeding about 6 ft. width. Over that, double sidefired arrangement is preferable, as in Fig. 6, in order to ensure even heat distribution.

Fig. 7 shows a "closed" design for temperatures below about 600°C., the gases passing through slots in the cover tiles.

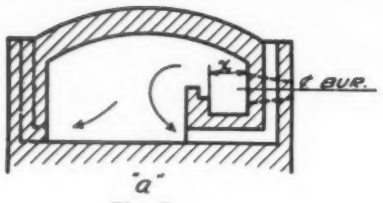


Fig. 5

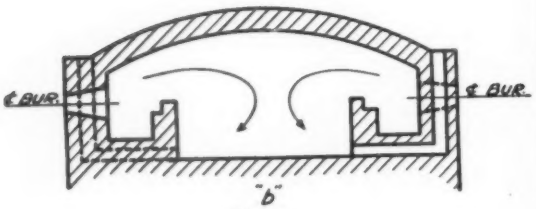


Fig. 6

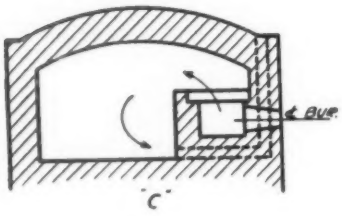


Fig. 7

For very high furnaces (5 ft. or so interior height) the burners are frequently arranged in two rows as shown in Fig. 8.

For most cases, flues are situated at hearth level in the burner sidewall and in both side walls in the wider furnaces to ensure an even heat distribution.

Fuel consumption of sidefired furnaces, if properly designed, should not be more than for an equivalent direct fired furnace except in the case of small furnaces.

The dimension between the inside of the furnace wall and the bridgewall is important. If the bridgewall is too far from the burner the temperature behind the wall will not be high enough to maintain efficient combustion, whilst if it is too close carbon may be deposited on it. It will also rapidly burn out.

The advantages of the underfired furnace are:

1. it can be used for heating temperatures up to about 1050°C. without rapid wear on refractories and consequent maintenance;
2. no special brick shapes are required and therefore, they are easy and cheap to replace;
3. temperature can be accurately controlled;
4. there is minimum oxidation of heating stock;
5. the design is adaptable to many materials handling arrangements.

The only serious disadvantage is the width required by bridgewall and combustion space, which is an important point in small furnaces and where floor space is limited.

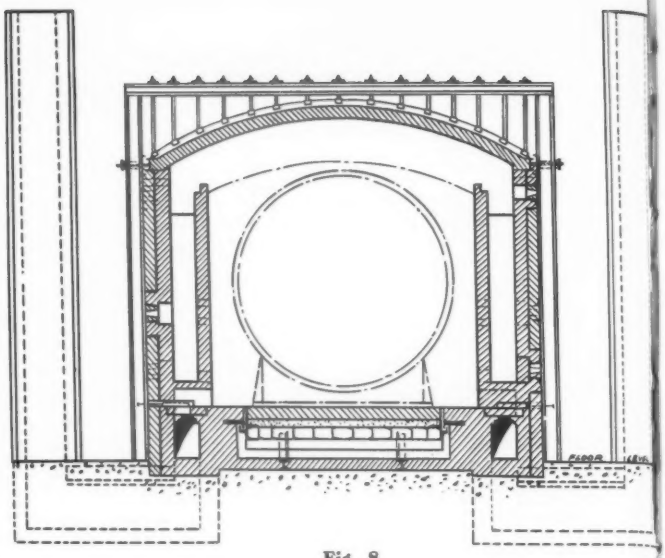


Fig. 8

Direct Fired Type

In this design the oil is simply fired straight into the heating chamber without any kind of baffle. The burners may be located either at the sides or the ends of the furnace and the flues may be located in roof, sidewalls or hearth.

Fig. 9 shows an arrangement which is quite successful for furnaces up to 10 ft. long. The flue or flues are in the roof directly above the burners. The velocity of the flame from the burner carries it beyond the flues. The gases, therefore, travel back across the hearth. The flame entrains part of the gases and carries them round again, resulting in good heat utilisation.

Fig. 10 shows a section of a long furnace where the burners on each side are staggered down its length and the flue ports are located between burners.

Most continuous types of furnaces are direct fired. Direct fired furnaces give a high velocity of gases in the heating chamber, with consequent rapid heat transfer and the complete utilisation of the radiant heat from the flame.

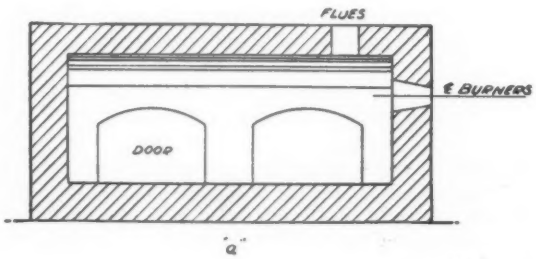


Fig. 9

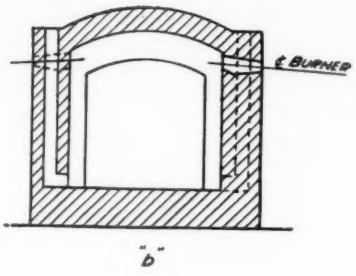


Fig. 10

Fairly complete combustion can be obtained from a good design furnace, but for temperatures under about 1000°C. temperature control is very difficult because of the difference between flame temperature for combustion and temperature required for heating.

The advantages of the direct fired type of furnace are that high temperatures are possible, and there is long life of refractories with properly designed furnaces.

The disadvantages are difficulty in maintaining even temperature distribution, and a tendency to scaling of the stock being heated.

Muffle Type

There are three general designs in this category:

(a) where the heating material is muffled, as in Fig. 11;

(b) where the flame is muffled and the heat radiated from the outside of the muffle to the heating material in the furnace, as shown in Fig. 12;

(c) the semi-muffle arrangement, as shown in Fig. 13.

In muffle furnaces oil consumption is high for a given cutput of material being heated. This is because of the great temperature difference that must exist in order to force the heat through the muffle. This temperature difference can quite easily be of the order of 100°C.

The Application of Furnace Types

First, let us see what some of the important heating processes are in industrial furnaces and the essential requirements of the process. The Table in Fig. 14 gives some of these, classified according to temperature.

Now let us see which method of heat application or furnace type is suited to the above cases and the factors which determine the selection, disregarding for the present any influence of material handling.

Temperature Range up to 150°C.

Most furnaces for steel treated in this range are of the oil bath type, where the oil bath is contained in a cast iron pot heated externally. Usually the pots are quite small, say up to about 2 ft. diameter and 2 ft. deep, and the amount of oil per hour is also small. The oil is usually burnt in a very small combustion chamber within the furnace into which the pot is built. Actual combustion temperature may be quite high, but the amount of hot gases produced is small.

Usually temperature control of the bath is very important, and the steels tempered at such low temperatures are usually of a special nature.

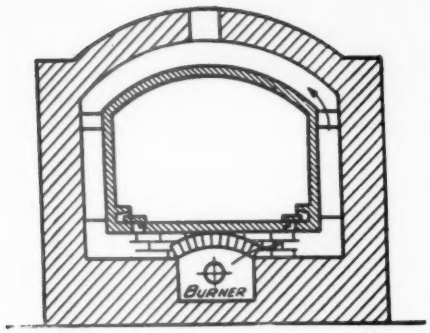


Fig. 11

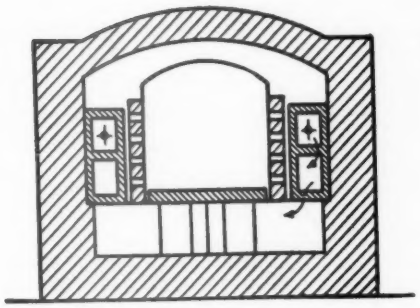


Fig. 12

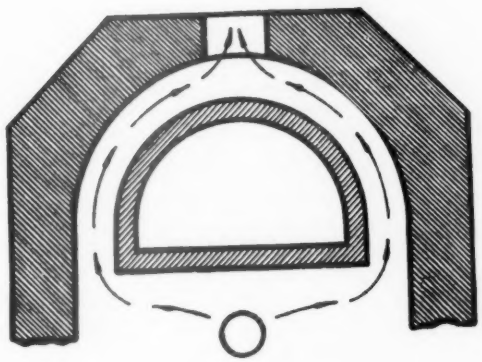
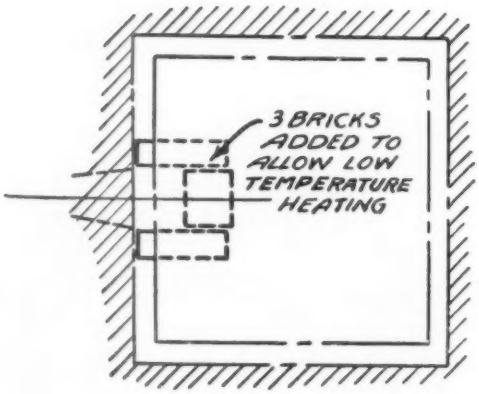


Fig. 13

Temperature, Deg. Cent.	Processes
0– 150° C.	Tempering of hardened steel
150– 550° C.	Tempering of hardened steel, core ovens
550– 750° C.	Tempering, quenching of high-speed steel, preheating, annealing
750– 950° C.	Hardening, annealing, case hardening, carburising, cyaniding
950– 1050° C.	Hardening, annealing, case hardening, carburising, heating for bending and forming
1050– 1200° C.	Heating for forming, drop forging and pressing, hardening of high-carbon steel, annealing of alloy steels
1200– 1650° C.	Heating for forging and rolling

Fig. 14



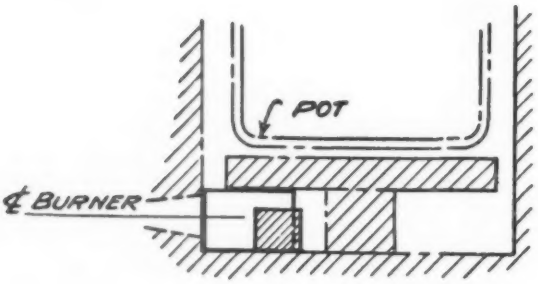


Fig. 15

Temperature Range 150°C—550°C.

Tempering in this range includes common steels which are done in large quantities and often with quite an allowable variation in accuracy. Thus the selection of a pot or oven type of furnace will depend upon the degree of these two factors.

The pot furnace, in which special liquid salts are used as heating mediums, is ideal for tool steels, high carbon steels and alloy steels, because of the clean surface produced and the very accurate temperature control possible. Such pot furnaces are similar in construction to those mentioned previously. Figure 15 shows an arrangement for the brickwork for a pot furnace.

For quantities of large sized pieces in medium carbon steel, the oven type furnace is more suitable. Underfired, overfired, or closed side fired are the only types that can be used because of the low temperature requirements.

Temperature Range 550°C—750°C

Heating operations in this range include:

(a) tempering of special steels at high temperatures.

(b) quenching of very high grade steels in a salt bath at these temperatures giving hardness without any breaking, warping or cracking which would occur if these steels were quenched in cold liquids.

(c) pre-heating of parts in pot or oven type furnaces prior to rapid heating in hardening salts or lead bath. The pre-heating prevents sudden stresses in the steel.

(d) annealing of heat treated parts or castings. This is probably the largest call in this temperature range.

The oven type furnace is generally used and almost always an underfired design for furnaces under 4 ft. in width.

Larger units are usually closed, sidefired, or overfired, and their size can be almost anything.

Temperature Range 750°C—1050°C

This range includes the majority of furnaces and almost all possible kinds are built. They may be:

(a) pot furnaces;

(b) portable oven furnaces; or

(c) large oven furnaces.

In the pot furnaces, high temperatures salts or lead are the heating medium and the process is generally cyaniding—the steel being heated above the critical point and quenched with water or oil to obtain hardness. Salt baths give an absence of oxidation, rapidity of heating due to the high rate of heat transfer from liquid to metal, uniformity of heating and reduce the tendency to warping and cracking. Also, a portion of a piece can be hardened without affecting the rest of it.

Good results are obtained by firing the pot from beneath, protecting it from direct flame impingement by some form of refractory shields.

The burners should be arranged so that the gases circulate as much as possible around the pot before venting at the top.

The portable oven furnaces include those for hardening dies, high carbon steels and ordinary steels and for annealing small steel and C.I. parts. They are usually underfired except in the case of continuous designs.

The large ovens are used for all kinds of things such as carburising, heating for bending of plates, pipes etc., and rolling of thin sheets.

Sidefiring is by far the most common and best arrangement for work at these temperatures.

Muffle furnaces for enamelling are included in the group of furnaces in this temperature range.

Temperature Range 1050°C—1200°C

Except for annealing of stainless steel, the hardening of high speed alloy steels and a few other processes, furnaces in this range are all for the heating of steel for forming, drop forging, pressing and similar operations.

The number of furnaces in this range is very large. Small underfired furnaces with carborundum hearths and linings are in common use for high speed steel and die hardening. The rest in the group are generally sidefired or direct fired.

If properly designed, the sidefired furnace is better than direct fired, because it gives greater temperature uniformity and less sealing, with consequent less wear on dies and tools. Underfired and overfired furnaces are never successful in this range, except as mentioned above, due to the high temperature that would exist below and above the hearth, which would cause very short life of the refractories.

Temperature Range above 1200°C

Direct firing is the only suitable means in this range, which includes such processes as heating of ingots, billets for rolling, metal melting, etc. With good furnace design good temperature uniformity is obtainable, since radiation is very active above 1200°C and tends to equalise the temperature, and the difference between flame and furnace temperature is now beginning to diminish.

Furnace Capacity and Size

There are three main considerations in determining the general type of furnace for a given heating problem as follows:

1. application of the heat in the fuel;
2. required furnace capacity and size;
3. mechanical handling of the heating material.

All these points are interconnected and must be considered together in determining the furnace.

The factors which influence size determination are:

1. the amount of material to be heated in unit time;
2. sizes of the pieces to be heated and the time required for the particular heating process;
3. heating rate possible with the particular furnace arrangement.

First Factor

This is extremely flexible and variable and its accurate determination requires a knowledge of such data as whether the supply of material is steady or intermittent, maximum and minimum amounts of material, etc.

It is usual to refer to production as so many pounds or pieces per day. A furnace designer must find out in how many hours this amount is to be heated, whether the supply of material will be fairly constant over this period and, if not, what maximum production will be reached in maintaining the average.

Such data often requires tedious investigation, but is always worth while, because unsatisfactory results *commonly* arise from an incorrect analysis of this question. A furnace that is too large can be very inefficient and one too small must be forced, usually resulting in a short life and high upkeep cost.

Industrial furnaces are rated on the pounds of steel heated per hour and the best practice is to determine in every case the average weight of material to be heated per hour, the minimum and maximum rates and the percentage of time during which these rates will prevail. From these considerations the size of the furnace can be fixed so that it will be working at its most efficient rate for the greatest amount of its time, and at the same time allowing maximum production to be coped with when necessary.

Second Factor

The heating time required depends on the dimensional size of the piece and the metallurgical requirements of the process.

Knowing the pounds of material to be heated per hour and the weight of the pieces, the number of pieces to be heated per hour can be readily determined. From the heating time required for each piece the number of pieces which must be in the furnace at any given time is determined by multiplication thus:-

100 pieces per hour at $\frac{1}{2}$ hr. heating time each gives $\frac{1}{2} \times 100 = 50$ pieces in the furnace.

The hearth area required to hold the required number of pieces can now be determined. This area must then be checked against the third factor.

Third Factor

This is the heating rate possible with the particular furnace arrangement concerned. By this is meant the amount of heat which can be liberated without injury to the furnace brickwork. This is expressed by the amount of steel heated per sq. ft. of hearth area. For mild steel the following figures are acceptable:-

up to 35lb./sq. ft. for underfired furnaces
" " 50lb./sq. ft. " overfired furnaces
" " 70lb./sq. ft. " sidefired furnaces
" "100lb./sq. ft. " direct fired furnaces
" " 25lb./sq. ft. " muffle furnace for enamelling C.I. pieces
18 - 25lb./sq. ft. " muffle furnace for sheet enamelling.

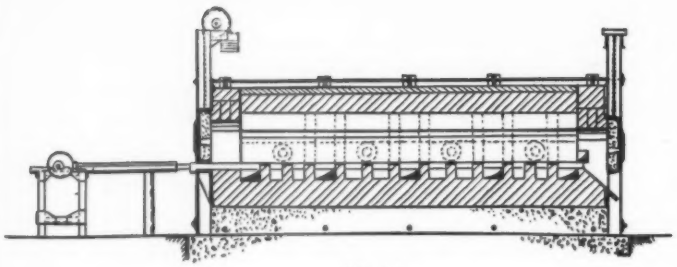


Fig. 16

Thus the final interior dimensions may be a compromise between the second and third factors.

Material Handling

This can be divided into two groups: (1) in the furnace; (2) outside the furnace. We will consider only the former.

This factor should be considered along with the other two just described in selecting a suitable furnace for a given job.

The method of handling material through a furnace can be classified broadly as follows:-

(a) batch type
(b) pusher type
(c) car type
(d) rotating hearth
(e) chain conveyor
(f) roller hearth
(g) moving hearth

There are, of course, many variations of each design; each arrangement has its advantages and limitations. In the selection of a suitable method of handling for any conditions the various types should be considered in their order of simplicity which is that given above, because complication in design can be costly initially and in upkeep. Each type should be proved on paper to be better in economy and operation than a simpler arrangement before it is seriously considered.

(a) *Batch Type.* This comprises furnaces in which the material being heated remains in the same position during the whole of the heating time. The box type furnace, of which there are countless variations, is the simplest.

When a number of pieces is to be heated in preparation for a forming operation, such as in drop forging, a "continuous" batch operation is usually followed. This means, as one piece is removed another cold piece is introduced into the furnace, working the furnace all the time from one side to the other, and always leaving a blank space between the cold piece charged and the next hot piece to be withdrawn. This prevents any chilling effect on the hot pieces by the cold pieces.

Thus batch types are best for small and intermittent production except in certain cases such as in the continuous batch process.

(b) *Pusher Type.* This method of handling is very common for it is simple and has a wide range of temperatures application.

In construction it is similar to a batch furnace, except that it is further complicated by rails or guides on which the material slides. Fig. 16 shows such a furnace.

Underfiring is usually not satisfactory. The overfired design is all right where the furnace is not too wide and the temperature does not exceed 980 - 1000°C. Above this the direct arrangement is almost exclusively used.

There are all sorts of pusher mechanisms, for example, rack and pinion, lever, and air cylinder pushers.

(c) *Car Type.* This is one of the most commonly found for steel or C.I. annealing in quantity. It is merely a batch furnace with a very convenient labour-saving method of handling by a truck or car on rails, which is simply loaded up outside the furnace, then pushed into the furnace forming the loaded hearth and again pushed out of the furnace at the end of the annealing cycle.

Such a furnace can be ruggedly built and be capable of accurate temperature control. It can last for long periods without repairs.

Sand seals are incorporated on both sides of the car to prevent air infiltration and protect the running gear from heat.

Sidefiring is the best arrangement. Direct is sometimes used but will not give quite the same degree of temperature control. Overfiring is sometimes used. Car types are used for low temperatures as in core ovens, etc.

(d) *Rotating Hearth.* This design is becoming more popular for the heating of irregular shaped pieces. It saves labour, for one operator can charge and remove the pieces from adjacent doors.

Temperature control is reasonably good. Material is charged on to a moving annular hearth and makes one revolution through the hot zone before being removed.

Initial cost of such furnaces is high but the upkeep cost is low when used for temperatures not exceeding about 1050°C. The driving mechanism is well away from the hot zone.

Fig. 17 shows a rotating hearth furnace. These furnaces have been used to temperatures of 1250°C., direct fired, but troubles then occur due to slagging of the refractories.

Normally, sidefiring is the better method.

(e) *Chain Conveyor.* This is ideal for many operations, but the difficulty lies in the fact that the advantage is too frequently theoretical and in practice gives endless trouble.

The work is carried through the furnace and often discharged on to a chute or conveyor. The mechanism must be sufficiently robust and suitable alloys and materials of construction used. There are a number of variations of conveyor-flight, chains carrying the material across them; chains with fingers or other attachments.

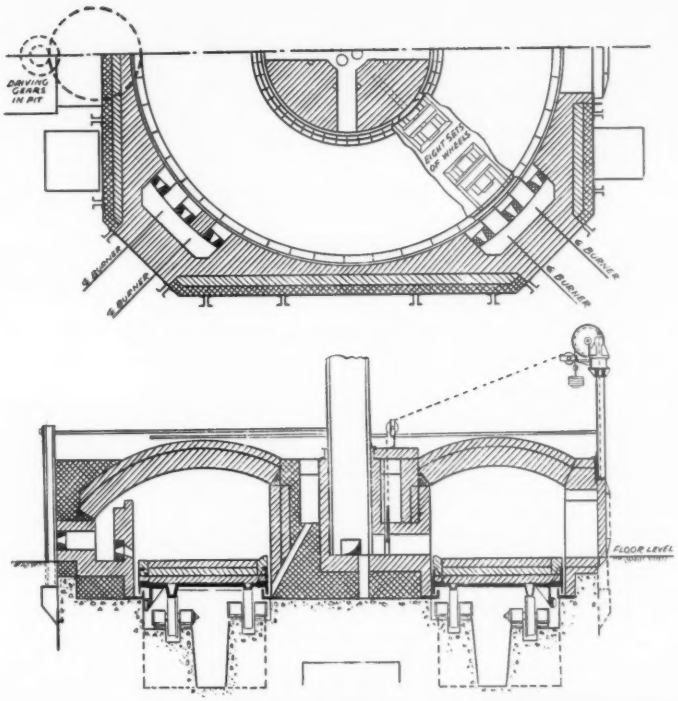


Fig. 17
Rotating hearth furnace

Fig. 18

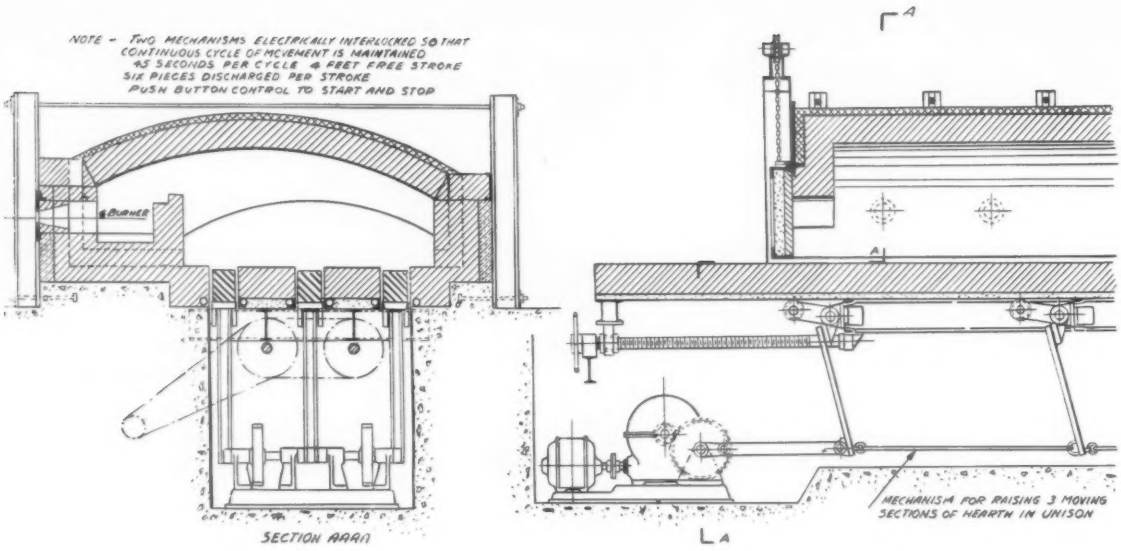

NOTE - TWO MECHANISMS ELECTRICALLY INTERLOCKED SO THAT CONTINUOUS CYCLE OF MOVEMENT IS MAINTAINED
45 SECONDS PER CYCLE 4 FEET FREE STROKE
SIX PIECES DISCHARGED PER STROKE
PUSH BUTTON CONTROL TO START AND STOP
SECTION AAAA
MECHANISM FOR RAISING 3 MOVING SECTIONS OF HEARTH IN UNISON

Fig. 19. Form of walking-beam type of moving furnace hearth

Process	Method of Material Handling	Method of Heat Application
Group A :		
Drying	Car type	Underfired
Drawing	Batch	Underfired, overfired, or closed sidefired
(1000 lbs./hr.)	Chain or moving hearth	Underfired, overfired, or closed sidefired
	Pusher type	Underfired or closed sidefired
Group B :		
Annealing or hardening		
(2000 lbs./hr.)	Batch	Sidefired or underfired
	Car type	Sidefired or overfired
	Pusher type	Sidefired or overfired
	Chain or moving hearth	Sidefired or overfired
	Rotating hearth	Sidefired
	Rotary muffle	Indirect-fired
Carbonizing	Rotary muffle	Indirect-fired
	Car type	Sidefired or overfired
	Pusher type	Sidefired
Forming	Batch	Sidefired
	Pusher type	Sidefired
Group C :	Batch	
Forging and rolling	Pusher type	Direct-fired
(4000 lbs./hr.)		Direct-fired

Fig. 20

Flight Conveyors—These are the most common type but often failures occur due to using wrong material of construction for the furnace temperature. Refractory blocks or some similar refractory flights are often employed.

Chains—These are useful for car axles and pieces of tapering diameter.

Fingers—Here the chain can be easily protected from the furnace heat.

Any chain conveyor to be a success must be reliable, otherwise the increased fuel consumption in heating the chain, added to cost of upkeep, more than offsets labour saving.

Overfiring and sidefiring are the best arrangements although direct firing is used.

(f) *Roller Hearth.* Their temperature range is limited to about 1000°C. for satisfactory service. Their design needs careful thought because moving metal parts—the rollers—are exposed to considerable heat.

Due to roller strength when hot the width is usually limited to about 2 feet. Fig. 18 shows a very successful furnace at British Tube Mills for continuous tube annealing.

(g) *Moving Hearth.* This includes various devices designed to move material through a furnace by means of a mechanism which itself remains inside the furnace at all times. One of the most common types is the walking-beam shown in Fig. 19. The best arrangement is usually sidefiring.

They can be used satisfactorily for temperatures up to about 1200°C.

Application of Heating Arrangements and Materials Handling

We can divide the various heating processes into three broad groups for methods of material handling :-

Group A	200°C. - 550°C.
Group B	550°C. - 1050°C.
Group C	1050°C. - 1350°C.

The Table in Fig. 20 shows at a glance the method of heating and material handling for the three broad groups.

Selection of Method of Material Handling

The best we can do here is give the way to approach and determine this question for a given set of conditions. The idea is the same in all cases but the data to be worked on will differ widely.

Assumptions

(1) All furnaces compared—oil fired.
(2) Production assumed to be steady—not intermittent.
(3) Same amount and size of pieces heated/hour in each furnace compared.
(4) Same heating process in each comparison.
(5) Open type furnaces—no pots or muffles.

For these conditions, the various kinds of furnaces in the three temperature groups can be compared as examples of the method, by consideration of the four principal factors which determine the best method of material handling, viz :-

(1) fuel consumption
(2) cost of furnace upkeep
(3) depreciation charges on furnace investment.
(4) labour saving.

	Gallons per Ton
Group A :	
Batch	15
Chain conveyor	18
Group B :	
Batch	20
Rotating hearth	18
Pusher-direct	20
Pusher-pans	30
Alloy chain	24
Group C :	
Batch	30
Pusher	26

Fig. 21

The object of comparison is to see whether a certain continuous arrangement, as compared with batch operation or some other continuous method, will save sufficient labour to pay for its installation and for any disadvantages in fuel efficiency or upkeep cost. This is solved by determining the comparative total cost of the factors—fuel, upkeep and depreciation—over a period say, of one month.

This data cannot be entirely accurate in its determination but some general average figures will be assumed for the three groups.

Fuel consumption is worked on the following production basis :-

Group A	1,000 lbs./hour
Group B	2,000 lbs./hour
Group C	4,000 lbs./hour

Using 250 working hours per month, monthly fuel costs are based on the average oil consumptions per ton of steel heated (see Fig. 21).

Upkeep involves life of refractories and metal parts and power for mechanical drives. The monthly cost in this case is determined by finding the type of furnace required in each case, assuming the best materials of construction and replacements on the average life given in Fig. 22.

Monthly charges for depreciation are determined by estimating the cost of the furnace required and assuming the same life for all of the furnaces in each group. Depreciation, interest and taxes are calculated according to usual accounting practice. The table in Fig. 23 gives comparative costs.

The difference in the totals for any two types in each group represents the amount to be saved in labour to make the more expensive furnace pay. The importance of fuel economy should be noted.

Average Life of Furnace Parts

Refractories

Group A :

No replacement

Group B :

Underfired hearths	6 months
Bridgewalls	12 months
Sloping floors	12 months
Level floors	36 months
Arches	18 months
Muffles	20% yearly replacement

Group C :

Arches	6 months
Door jambs	3 months
Bridgewalls	3 months

Weekly patching of door jambs and hearths

Metal Parts

Deg. Fahr.	*Cast Iron*	*Alloy*
400 –1600	*	
1700	1 year (min.)	3 years
1800	5 months	2 years
1900	1 month	18 months
2000	Not used	6 months

* Will last as long as useful life of the furnace

Fig. 22

The increase in maintenance costs for continuous furnaces over batch is small and would soon be offset in the saving of a man's wage. A word of warning—the foregoing was given to show you how to make a logical approach and the final results shown could be quite different under different conditions and with different fuels.

So much for the different designs of furnace and the approach to be made in determining the right design for a specific purpose. Now let us turn our attention to the actual operation of furnaces.

Furnace operation can be by one of the following methods :-

(1) hand operation

(2) semi-automatic operation

(3) fully automatic operation.

Hand Operation. This is still the most common form, where an operator must light his burner, control the oil supply through the burner and control the air supply through the burner and in some cases also control secondary air. Without any instruments at all to aid, this method is very much hit-and-miss where efficient combustion, temperature control and furnace control generally are concerned. However, in many cases the results either are, or appear to be, quite satisfactory and to go to the expense of any sort of automatic control would be quite unnecessary.

Cost per Month, Pounds.

Type	Fuel	Upkeep	Depre-ciation	Total
Group A :				
Batch	164	12	10	186
Chain Conveyor	197	22	29	248
Group B :				
Batch	440	8	16	464
Rotating hearth	395	10	115	520
Pusher-direct	440	40	32	512
Pusher-pans	650	49	33	732
Chain Conveyor	520	30	84	634
Group C :				
Batch	1320	125	38	1483
Pusher	1140	165	88	1393

Fig. 23

Semi-automatic Operation. Usually this implies an automatic control of oil and sometimes air supply as well to a furnace either by the high-low flame method (which is probably the more common), or a floating control. The apparatus is only semi-automatic, because it is necessary to shut down and relight the burner manually.

Normally it is not possible to obtain good atmosphere control on both the high and low flame settings, because the apparatus is generally only designed to control oil and air going *through* the burner—it does not control the induced air. Consequently one finds too much air at the low flame setting.

Fully Automatic Operation. Generally this implies a burner which can operate continuously without any manual aid. The burner shuts itself off and ignites again by automatic means. In the on position a given rate of oil is delivered through the burner nozzle—(2, 3, 4, etc. gallons per hour) and on reaching furnace temperature or boiler pressure the oil is shut off until the temperature or steam pressure goes down to some predetermined setting, whereupon the burner again ignites and so on. Such burners are usually only found on boiler installations.

I would now like to make some observations on temperature measurement.

Temperature Measurement

Although, as is usually the case, the incentives for better temperature measurement resulted from the demands for better product, the use of better pyrometers has also improved the operation of industrial furnaces and increased the opportunities for more accurate design of furnaces, by the collection of reliable data on the performance of furnace building materials. Some of the benefits to furnace operation

resulting from the use of temperature measuring devices are :-

(1) greater fuel economy;
(2) reduction of heating time by eliminating the margin of safety necessary with the old methods;
(3) reduction of labour;
(4) longer furnace life by elimination of unnecessarily high temperatures in the furnace;
(5) greater temperature uniformity.

Most pyrometers belong to one of four general classes :-

(1) thermoelectric;
(2) low-temperature;
(3) radiation;
(4) optical.

The thermoelectric pyrometer is based on the fact that when two wires of dissimilar material are heated in contact with each other, a very small electric current is produced in these wires, the amount of which has a fixed relation to the temperature of the junction of the two materials.

Low-temperature pyrometers are usually of the expansion or resistance types. The expansion type depends on the constant relation between the expansion of gas or of a solid rod when heated and the temperature to which it is heated. They are usually only suitable for temperatures below 550°C. For the resistance pyrometer, the relation between the temperature of a coil of wire of certain material and its corresponding electrical resistance is utilised.

The radiation pyrometer has no parts in the furnace heat and is based on the measurement of the heat emitted by black-body radiation through an opening in the furnace wall, or by sighting into a closed refractory tube in a furnace wall to prevent interference from smoky conditions.

The optical pyrometer is also entirely out of the furnace and depends upon the measurement of the amount of light given off by a hot furnace or body.

The purpose of most furnace temperature measurements is to measure :-

(1) the temperature of the furnace gases;
(2) the temperature of the furnace walls;
(3) the temperature of the heated material.

In the usual furnace operation these values are not the same, and considerable confusion results from failure to keep them separate in considerations of the temperature measurement.

The distribution of temperature in furnace gases varies with the design of the furnace. For example, in direct fired furnaces, the flames of combustion are developed in the heating chamber. If the furnace is properly designed, these flames do not strike the heating material directly, but are cooled by radiation and convection to the furnace walls and by radiation

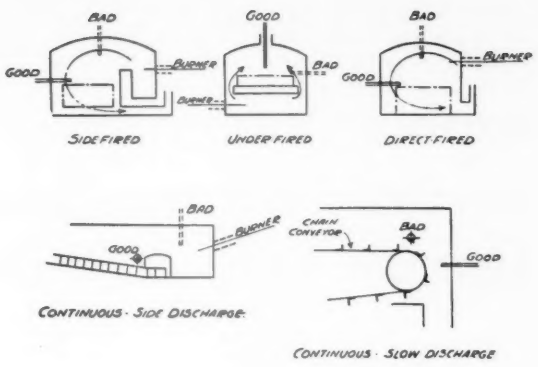


Fig. 24

to the material, so that by the time the gases come in actual contact with the material they are at the average temperature of the furnace. A measurement of the actual flame is therefore much higher than the average furnace temperature and such measurements are the greatest cause of confusing results.

Thermocouples should never be located in the direct path of a burner. As a general rule they should be located near the material being heated away from any point of cooling by infiltrating air and out of the way of material being handled in and out of the furnace. Fig. 24 shows good and bad locations for several common applications.

The measurement of wall temperatures is different from that of gases and is difficult unless a pyrometer is inserted through the wall to a point within about ½" of the hot face. Radiation and optical pyrometers are effective for wall temperature if the atmosphere of the furnace is fairly clear, otherwise they measure the gas temperature.

Much the same difficulty applies to actual material temperature measurement. In determining material temperature after it has been taken from the furnace, care must be taken to keep the iron oxide (scale) removed, because this has a much lower temperature than the material itself for it cools so very much faster. Many erroneous readings have been taken because of the neglect to observe this precaution. So much for temperature measurement.

We have now discussed at some length the design of efficient furnaces and something of their operation, but one very important thing still remains—a word about the oil burners and their fuel and air supply.

You can have the best designed furnace in the world and ruin its chances of success by not providing it with suitable, good, manufactured burners. The burner is a most vital part of the complete installation if satisfactory and economical combustion of the oil is to result. Briefly, the secret lies in atomisation of the oil into a very fine mist and its ultimate adequate mixing with air for complete and efficient combustion, thus projecting the mixture into the furnace to give the right type of flame and flame envelope.

(concluded on page 569)

PRODUCTION CONTROL AS APPLIED TO SMALL AND MEDIUM SIZED COMPANIES

by F. T. HUNTER, A.C.A., A.C.W.A.

Presented to a Joint Meeting of the London Section of the Institution and Croydon District Sub-Branch of the Institute of Cost and Works Accounts, 4th March, 1954.

PRODUCTION Control is perhaps, one of the most controversial subjects upon which a speaker can embark. Most of us have some strong convictions, to be defended through thick and thin. Even the most glaring evidence of the failure of some pet idea is dismissed as a failure of the personnel carrying out the idea, and never a failure of the idea itself.

The schemes that are produced range from the most frightening complexity and detail, to an almost equally frightening simplicity and reliance upon the memory of one or more individuals in the particular organisation.

Doubtless everyone here this evening has met the executive who thinks that the golden rule in business management is enough charts, graphs and statistics to paper a good-sized house, and the extreme opposite who says: "I don't want any figures and reports, I only have to walk round to know whether everything is in order."

Extremes, either in people or in systems, are, surely, almost always misguided and the aim should be to have just the right amount of reporting and control to ensure that the people who should know do, in fact, get to know what is happening, and that the control operates as nearly automatically as it is possible for any system to operate, thereby indicating the actions necessary to deal with the day-to-day crises and longer-term planning that occur in any business.

It is a widely-held belief that a system can itself take action. This is, of course, quite untrue, and there must always be the intervention of a person before any action takes place. The system only indicates the action required, and it follows inevitably that a system is only as good as the action it generates, or, indeed, is likely to generate. This raises very many most difficult problems, for which there is quite insufficient time this evening, and it must be assumed for our purpose that there would be staff of adequate quality both to decide what the appropriate action is, and then to take it.

In the smaller businesses it may well be that more than one function is performed by a particular executive, merely because each individual function does not represent a full task, but it should always be recognised that the functions are still distinct, and must be performed by someone, no matter what his official title may be.

Significance of Smaller Companies

The particular significance of the small and medium sized companies is that the major part of the industrial output is in their hands. There are many more companies of smaller size than there are giants. The tendency is usually to think in terms of large organisations, and to think of control schemes in those terms. It is far oftener, however, really necessary to think in terms of small concerns and to trim the proposed control schemes so that the essentials are provided without frills. There are, so often, the things that it would be very nice to know, but the particular concern does not have the spare resources to spend money on controls that can be dispensed with.

This is not to say, however, that there are any basic principles which do not apply equally to large and small companies. Every manufacturing concern, of whatever size, has the same set of basic problems as any other manufacturing concern at least of a similar nature. The detail solutions evolved may differ widely between similar concerns, because the whims and fancies of the designers are different or the plant shows some differences, and not the least because there is seldom, if ever, one solution only to any set of problems.

But let me emphasise that it is the solution and not the problem that has differed.

Types of Manufacture

Production Control, and the determination of basic rules for its conduct, is made exceedingly difficult because there are endless methods of manufacture.

Perhaps there are two basic types, continuous and intermittent. An example of continuous operation is wire-covering. General engineering would be intermittent, so called, apparently, because the parts will lie untouched between operations. Clearly the bulk of manufacture is intermittent.

There are a number of classes of manufacture, and the Management Handbook lists seven, viz.:

1. one order for one piece or product never to be reproduced.
2. one order for several pieces or products never to be reproduced.
3. repeat orders at irregular intervals for one or a few pieces or products.
4. repeat orders at irregular intervals for many pieces or products.
5. repeat orders at uniform intervals for one or a few pieces or products.
6. repeat orders at uniform intervals for many pieces or products.
7. continuous or standing orders for the same piece or product.

It is clear that a method of Production Control that suited Class I, obviously a jobbing shop, would probably be far too elaborate for Class 7 where long runs are involved. As a generalisation that list of classes of manufacture is also a list of the order of difficulty of control, No. I. the jobbing shop, being clearly the most difficult. It is also obvious that the piece or product may be very simple or of a most complicated nature requiring the highest skill and control.

Thus, no matter how vague and general this Paper might be, someone can always object that the solution propounded does not suit his business because of some unusual feature therein.

Again, however, it is only the solution to a basic problem that might not suit. The basic problem is, almost without exception, one that faces everyone else at least in a similar trade.

It is, incidentally, another widely-held conviction that no two businesses are alike or have the same problems, but my own experience has been that the same problems come up in business after business with monotonous regularity, not only in similar businesses, but in those of a widely diverse nature.

In this Paper, therefore, I am going to try to avoid precise solutions to precise problems, but will suggest what the basic problems are, and how they might be tackled in smaller companies.

Definition of Production Control

The Institute of Cost and Works Accountants defines Production Control as:

> "the direction of the material procurement and production activities of the business in order to ensure that material and production facilities, as specified by the technical functions, are available to carry out the planned programme of the business and that the maximum utilisation of production facilities is achieved."

Material control is included under the general heading of Production Control, but Purchasing is excluded on the grounds that it is a technical function, whereas Production Control is an administrative function. Purchasing, however, operates mainly at the behest of Production Control, and many companies include the purchasing function under the Production Control umbrella for that reason.

The Institute also considers that it is not a function of Production Control to lay down operating times, for example, nor to prepare operation layouts, but there are many companies where Production Control does embrace many of the technical functions of this kind.

I am not aware of the views of the Institution of Production Engineers on this point.

To reduce the Production Control function to simpler language it could be said that there are four aspects, viz.:

1. laying the plans under which the company is to operate.
2. issuing the necessary orders to give effect to the plans.
3. ensuring that the plans are carried out and that services, such as tools, are ready when required.
4. reporting progress, and taking corrective action where necessary.

Laying the Plans

Plans of any kind cannot be laid down without some detail upon which to work.

In the book, "Production Planning", by John W. Hallock, in Chapter II, seven essentials are listed:

1. Material.
   How much and what quality?
2. Time to obtain material.
   How far ahead must purchase orders go out?
3. Plant Capacity.
   How much can be produced?
4. Methods to be used.
   How should an operation be performed?
5. Operation Times.
   This is not quite the same as Item 3, the Plant Capacity. Under Item 3 the speed with which a lathe is capable of removing metal would be listed. Under this Item the application of that fact to the particular job in hand would be listed.
6. Quality or Quantity?
   How far can quality be sacrificed to quantity, or to what extent does the need for high quality slow up production?

7. Method of Control of Production.

   Who is allowed to upset programmes and to what extent? It is, often, a sad fact that many hours of labour by the planners are rendered quite useless by a quick change of programme, to say nothing of the chaos caused in the shops.

If we accept the views of the Institute of Cost and Works Accountants, nothing of the above is the work of the Production Control. They are frequently driven mad under Item 7 but are regarded, when voicing some mild complaints, as obstructive, and as clearly operating a system where the "tail wags the dog." They are told that the customer is always right and the shops must always be ready to push in or out any order at any time.

Unreasonable Complaints

Like so many of these things, there are, doubtless, faults on both sides but it always seems to me a little unreasonable for a Works Manager to complain about paper-work and inflexibility, as they nearly always do, and then complain because the Production Control are unable to ensure that everything does just what it was supposed to do, particularly when the programme never stays stable for more than a few days. I saw a case recently where the programme was changed eight times in four days, with most hurt feelings on the part of the management because it was pointed out that (a) this was really no way to run a business and (b) some weeks of most expensive overtime in the Planning Section might now just as well not have been incurred. The Production Controller was unprintable for several days.

While the Production Control Department do not carry out the work listed above, they use it, and Hallock is surely correct in that they cannot work without it in some shape or form.

The extent to which a smaller company or, indeed, any company, would go into detail depends, of course, enormously at first upon the class of work under which the proposed job comes; is it short-run jobbing work, or is it a steady order where some careful detail planning would be worthwhile?

Basically, however, some decision must be made, after details such as material are settled, on :

1. how to do the job.
2. when it can start and finish.

Very often, it has to be admitted that quotations are made to customers, and delivery dates established on the slenderest evidence, almost no evidence at all, and one is forced to the conclusion that somewhere in the organisation there lurks a crystal-gazer, though the results of such a procedure would usually lead one to doubt the skill in interpretation of the crystal-gazer employed.

In smaller companies it is very common practice for no real attempt at planning to be made until the production order reaches the shops, and the foremen then decide how the job is to be done, and how long it should take. The British Standards Institution suggest, in their booklet on this subject, that this procedure has much to recommend it, and that flexibility is safequarded thereby.

On a later page it is said that there should be consultation with the foreman at the enquiry stage for approximate ascertainment of the time involved in manufacture, and for a quotation to be prepared.

I always have a feeling, however, that this is a bit vague, and that a much clearer idea should be established at the outset. It can make nonsense of estimates and shop loading if, when production is due to start, the foremen concerned change their minds completely on how to do a job.

Provided the necessary technical information is available at the enquiry stage, a little serious thought on method and time always seems to me to pay dividends.

If the technical information is not fully available, and I am often told this as an argument against spending time at the early stages on planning, quotations should really not be indulged in. How can you quote for making something when you don't know what it is?

The argument is often put forward that enquiries are so urgent that there is no time to do other than make quick guesses. This, surely, is very seldom really true, and it is quite unreasonable for a potential customer to expect a reply at such short notice that the potential supplier must be doing no more than merely guessing.

Importance of Time Estimating

The precise method of assessing the productive capacity required and so on may not necessarily be in terms of time at the outset. The nature of the manufacture may be quite simply scheduled in terms of number of pieces, or money value or some other factor, but ultimately, in my view, every effort should be made to convert into terms of time, because shop loading, control of actual against plan, cost of production, and so forth, are much more easily and accurately carried out in such terms.

Without, therefore, trying to think of all the various types of manufacture, and their particular problems, my view is that at the enquiry stage, sufficient analysis of the job should be made to determine, reasonably clearly, how it is to be done and in what sections of the factory, and how long it should take. Capacity can therefore be earmarked provisionally to enable a delivery date to be quoted, such capacity being earmarked firm as soon as the order is received.

I am not suggesting that there should never be better second thoughts, but it would be easier for everyone if better second thoughts were not the rule in every case.

I am well aware that, almost in direct ratio to the complexity of the product, this procedure becomes more difficult, but I still think that every reasonable effort should be made. There are not so many companies whose manufacture is largely composed of products the like of which they have never seen before, and most concerns have fairly clear ideas how they would carry out this or that kind of operation, and how long it should take.

The time assessments do not, for this purpose, have to be anything like as accurate as would be required for wage payment purposes, and any sensible management will always keep a reserve capacity "up their sleeve", to cover both the inevitable rush job and the errors that will occur in thinking out in the early stages both how to do the job and how long it should take.

Any large company, quoting for large orders, is, in my view, quite mad if it sends out quotations without having given most careful study to them. But many do this and seem to me to commit themselves to vast sums of money in a most casual and haphazard manner.

Material is usually known at the outset because the customer lays this down, or for a proprietary product the Design Department have said what is to be used. It is not really within the scope of this Paper to discourse upon the passion of Design Departments for very expensive materials, in short supply, with some very tricky problems in use.

The quantities to be used are in the main capable of fairly precise calculation, and the determination of a production programme largely determines the buying programme.

The provision of jigs and tools is almost the subject of a Paper in itself and I will come back to this presently.

Issuing Production Orders

Having somewhat briefly sketched the procedure to decide what is to be made and when, steps now have to be taken to issue definite production orders.

Many small concerns in fact do no more than issue a production schedule to the respective foremen, quoting on the schedule the order of procedure, finishing dates, and so forth. This has limitations, obviously, and would not be satisfactory where there was a multiplicity of parts of differing natures, all needing to be ready for sub-assembly and final assembly at specified dates. In such a case, some form of individual job ticket is probably required.

In whatever form the order is issued it must do these things:

1. definitely authorise production to take place.
2. indicate in sufficient detail how manufacture is to take place, e.g., tools to be used.
3. provide authority, where necessary, for material issue.
4. provide an identifying label for the job.

As a generalisation, the larger the concern the more elaborate must this paperwork be, and *vice versa*. In many of the smaller concerns, the paperwork is very little and great reliance is placed upon the memory and local knowledge of foremen, storekeepers and operators.

The nature of the production is of importance in this connection, and it is possible to visualise a small concern, with such a complicated production that very detailed paperwork is necessary, equally with a vast concern where the production is so simple that almost any paperwork would be superfluous.

With the average small to medium company, however, a simple order in schedule and individual ticket form, giving the essential information as to tools, dates, etc., is all that is necessary. If a schedule is used, the receipt by the foreman of the drawings is often his signal to start. He knows from the schedule when the job is required and it is left to him to plan his work to meet those dates.

This point is of the utmost importance in that every effort should be made to leave the foreman his flexibility. In the larger companies there is, probably, far less flexibility, and some concerns go so far as to lay down beforehand the individual machine which is to do a particular job. In the smaller places this is usually quite impractical, if not disastrous.

The issuing of production orders, more particularly in smaller companies, does not necessarily have to be in the quantities of any particular sales order. There may be several calling for the same parts, and judicious bulking to achieve longer runs is probably good sense.

Many piece parts may be controlled on a maximum-minimum basis, the quantities going through having only a global relationship to any periods assembly programme.

It is common to find in ordering systems booklets of operation and move tickets, used for wage payment purposes and to advise Production Control of the location of a job. There are endless varieties of these, some typed, some handwritten, some made out on a reproducing or printing machine from pre-prepared masters or plates.

Very often they are far too elaborate and expensive and do not really achieve their purpose. This is particularly true in smaller companies. The method of payment of operators can have much to do with deciding what to use, but it is often quite sufficient for each operator to have a card for the week, entered up by a foreman or inspector every time a job is completed and passed. So far as movement is concerned, a weekly report from the foreman of jobs cleared is all that is required. It is seldom necessary in small companies for there to be a record of movement between each operation within any particular department, and a record of movement from department to department is usually sufficient.

Ensuring that the Plans are Carried Out

When a quotation is sent out, production capacity is provisionally earmarked, and when the order is received the provisional earmarking becomes a firm booking.

It is, in general, most convenient for these bookings to be in terms of time, the number of hours required in the various sections of the factory, although it may be practical to compute the provisional bookings in some cases in terms of some other unit.

The firm booking should, almost always, however, be in terms of time.

Both the provisional and the firm bookings need to be recorded initially in two ways;

1. on a production schedule showing each section separately, and drawn up to allow each job to be entered under the date when performance must be carried out. Date in this sense probably needs to be no more precise than weekly, and attempts to plan on a daily basis are probably doomed to failure from the outset. The week for a piece-part must clearly be sufficiently far in advance of assembly to allow of adequate manufacturing and movement time.

   The schedules should be drawn up so that there is a clear indication of available capacity and capacity booked. One of the most commonly used types of schedule is a Gantt chart, but there are many others.

   The provisional bookings can be made in, say, pencil and the firm bookings in ink, or two different colours, or plain squares and hatched squares; there is an endless variety. Probably, one is as good as the other provided there is an almost instant picture presented.
2. the second entry should be on a load summary which shows the totals of the production schedule in figure form, indicating how many weeks ahead production is booked, provisional and firm.

   This summary could not, without becoming most elaborate, show where the inevitable gaps occur, and it will probably be sufficient that it assumes that all firm production follows without any gaps. The production schedule shows where the gaps are, and the load summary is only a guide to the number of weeks' work ahead, provisional and firm.

In addition to these records the shops require a schedule telling them what to do. It is sometimes argued that the shops do not need any schedule, but should be able to operate on the production orders which can indicate the dates when the job is required. From these the foreman can plan his work ahead.

Liaison with Foremen

However, it is, in my experience, much better to give the foremen as much advance warning as possible of jobs coming along in a fairly comprehensive form.

He can clearly plan his work to achieve production dates much better if he has a picture of what is ahead in schedule form, and if the picture covers not only next week but a week or so in advance.

Each week, therefore, schedules should be issued of all firm jobs for next week and say two weeks ahead, with notes of important provisional jobs that are in the "almost certain" category. The schedule would not necessarily authorise manufacture because the job ticket, if one is used, will do that, and material may not be drawn from stores without a requisition authorised by the Control.

During a week supplementary schedules would be issued for the inevitable rush jobs.

The production schedule, therefore, is prepared, perhaps, many months in advance of actual manufacture, whereas the shop schedule is only, perhaps, a week ahead.

When the production schedule has a job entered firm, the necessary material schedules should be passed to the Buying Department, with all necessary dates and full detail of the material required. Where some parts are controlled on a maximum/minimum basis the Buying Department can ignore these items, being entitled to rely upon the Control to see that the maximum/minimum quantities in vogue are still adequate.

If the Buying Department cannot obtain the material in time or to quantity the Production Control must, where necessary, alter the production schedule and agree new dates with the customer.

In addition, the Production Control must prepare schedules of tool and jig requirements, with dates. These either go to the tool room, or are contracted for from an outside tool-maker.

It is, perhaps, hardly worth saying that the Control should ensure that all necessary drawings should be on hand in good time, but it seems to be a commonly encountered complaint that drawings trickle in when the product is delivered and in service.

Again the drawing up of these schedules has, of itself, achieved nothing. They merely say what should be done. Someone has to do it and it is, perhaps, regrettable, but nevertheless essential, that someone else has to watch to see that it is done.

Progress Control

This watching function, commonly called progress control, may be simple or elaborate, according to the size or nature of the production but it basically has to do two things:

1. ensure that supplies such as material and tools are on hand at the right time;
2. ensure that production finishes at the right time.

It is fairly common in the smaller concerns for the Control on material supply, jig and tool supply, and the preliminaries generally, to be carried out by the same staff as prepare the production schedules, and the production schedule itself can be used for the purpose. Suitable colours can be employed to indicate the clearance of the various factors, and the release of the items for production. It is sheer waste of time to issue production orders to the shops unless the necessary supplies are ready and waiting. Each week, therefore, the Control can pass to the Progress Section lists of order numbers released for production, and these lists should be sufficiently far in advance to give Progress time to issue the shop schedules and production orders, if these are separate orders.

A similar procedure would be used for tool orders on the tool room, and Progress would control these in exactly the same way as a production order, but far enough in advance to ensure the tools being ready in time.

The Progress Section would prepare the shop schedules in duplicate, one going to the foreman, and the other being used for detail control, and

they are, of course, only concerned with jobs that have become firm.

As the production was completed the Progress Section would be notified, either by sending them a progress ticket or a daily list from the foreman, or some such method, and the jobs would be marked off as completed. The precise method of notification would depend upon the ordering system in use, and this can be one of almost literally hundreds. It could be practicable to use the job ticket upon which payment was made provided this did not cause delay in the Wages Office.

As the Progress Section is part of Production Control, and in a small plant the staff would probably be located together, there would be no need for similar entries to be made on the production schedule.

Shop Schedules

The shop schedules would be in such form as to indicate the movement of jobs from shop to shop and this might be quite sufficient from a Progress Section viewpoint. Production could, however, be of such a detailed nature that it was desirable to record the completion of each operation. If this was so, the form of process layout showing the operations to be performed could be duplicated to provide an operational control, both for time and quantities completed.

To try and show all operations on the shop schedule itself would almost certainly make it much too detailed and clumsy, and it would cease to have the virtue of giving a quick picture of the general position.

Thus, there need only be three basic records:

1. Production schedule, which records:
   (a) provisional programme;
   (b) firm programme;
   (c) provision of material, tools, etc.
2. Shop schedule, which:
   (a) provides the manufacturing programme for a time ahead;
   (b) records whether the programme is achieved or not.
3. Detail progress sheets, which control each operation, where this is required.

There are many frills and elaborations which could be introduced, but there is clearly insufficient time this evening to explore them.

Reporting Progress and Taking Action

Probably the most important factor in Progress Control is speed of notification when things go wrong. It is most desirable that advance notification of delays and shortages should be achieved if possible.

This is easy to say but not always so easy to achieve. In a small plant, probably the most satisfactory way is to have some progress chasers who keep up a constant liaison between the Control and the shops. The control clerks who are continuously entering up and watching the shop schedules will become so familiar with the various sections that they will instinctively become aware of likely delays and will give the chasers lists of jobs to be watched and pushed. The chasers will continuously keep the control informed of the position of these jobs and their sections generally.

Many jobs will, because of design difficulties, material hold-ups, or some such factor, be "chased" throughout their journey through the factory.

In addition, each week the Control should prepare two lists:

(a) jobs not finished to time, with an estimate of when completion will take place;
(b) jobs finished but, because of excess scrap, to a smaller quantity than required.

In both cases, the Control will have known the position on some of the jobs during the week and appropriate action will have been taken. But every Monday morning there should be a complete review of the position and the necessary action taken.

Where jobs are not finished to time, it may mean that the current week's shop schedule may have to be altered, and some job or jobs be retarded to a later week. This may mean telling the customers, although this is obviously not very desirable. The programme, however, may have enough slack in it to allow for minor hold-ups. It is always a very nice point to decide just how much slack or cushion there should be without wasting potential revenue earning productive capacity.

Where the product is essentially an assembly job, delay in one or more piece-parts can mean an alteration in the assembly programme many weeks ahead.

The Customer Problem

There are so many factors that influence the spare time available for completion of any job that one could write a separate Paper on it. Very often it is the customer himself who causes most of the trouble, by not making up his mind until the last minute, and then wanting the job yesterday.

The action to deal with delays may be overtime or a night shift, but there should always be top management sanction for this. It should not be left to the foreman. Most important factors of costs are involved, for example, and it is no exaggeration to say that much overtime and night shift working is embarked upon quite frivolously with little or no regard to the real points involved.

Where there is excess scrap, and a consequent shortage of numbers of parts, some concerns immediately put out replace orders; some have sufficient margins in the ordering quantities to allow of a review, say, every three months on long run jobs, and there are again several ways of dealing with the situation. What always has to be borne in mind, however, is that sooner or later productive capacity will be taken up in doing the same job twice. Rectification of faulty work has the same effect.

The slack or cushion may cover the position but it may happen that scrap or rectification reaches serious proportions and there is no cushion left.

The answer may well lie in much more rigid inspection at an early stage, and some increase in

the cost of inspection can be more than recovered in increased good output.

Whatever the answer to the precise situation may be, what is important is to insist upon a regular and systematic examination of the position. If this is not done, all the problems become "panics", everyone is driven frantic, and the general level and quality of production inevitably falls.

There should be regular reports to the management in such form that a quick picture is presented, with clear leads to the problems requiring action. Each meeting should end with some minutes stating quite precisely what is to be done, and who is to do it. The next meeting clears these points first, and ensures that what was agreed to be done has in fact been done.

Conclusion

This Paper has only sketched in the points to be watched. It could not cover all the detail in the time available.

No attempt has been made to illustrate rulings of forms, job cards, process layouts and the like. The discussion on these alone would last over many days apart from any questions of basic principles.

It is hoped, however, that what has been said will stimulate some useful discussion.

ABSTRACT

THE RATE OF "PACED" MAN-MACHINE SYSTEMS

by R. CONRAD, Ph.D., M.A.*

METHODS of production in light industry are particularly characterised by the widespread and increasing use of automatic machinery, and flow systems using automatic conveying of materials. The role of operatives in these systems is typically to feed material into, or to process material coming from, an automatic machine. But not uncommonly, after a machine has started the flow, material passes from one operative to another on a conveyor.

Although there are many varieties of these systems, essentially the operative is "paced", particularly when every machine operation must be matched by an operative cycle—e.g., feeding jars into an automatic filling machine or assembling electric lamps on rotating heads. In such cases, the pacing is strictly periodic. Where material passes between operatives, the time interval between items of work will tend to be irregular.

So long as the system is producing, operatives themselves have little if any control over the pace. Generally only a key operative can stop the system, and rarely can its pace be varied. The available time for the human operations is thus predetermined and frequently constant. The ideal operative is one who can always match this predetermined time.

The processing time required by the operative ultimately depends on a number of psycho-motor thresholds, in such a way that there is an absolutely minimum time, without there being an absolutely maximum time. The distribution about the mean time is not normal, but is probably log-normal. In general, it will be found that about two-thirds of the times are shorter than the mean time, so that the mean value is much longer than the mode. The slowest time is 3—9 times longer than the fastest. The long times are not accidents of the observation period which can be ignored in planning. They are typical of these distributions.

If the flow rate or machine speed is set at a value equal to that of the operative's average, on one-third of the occasions the operative will require more time than the system permits. On the remaining occasions, the operative, having completed the cycle in less than the mean time, will wait idly for the next item. It by no means follows that these two will balance out. In practice, the flow rate must be sufficiently slower than the operative average rate so that the probability of several successive times occurring longer than the machine time is very small. This further increases the amount of time that the operative waits rather than works. On the other hand, bringing the flow rate or machine speed up to that of the operative average will inevitably tend towards periodic stopping of the system.

The systems, therefore, have in them an inherent inefficiency in the form of inevitable delays during which either operatives wait for work, or the work waits for operatives. This is due to the fact that there is no single operative time to which the mechanical side of the system can be matched. In planning the system one is faced with a cycle-time distribution of considerable spread, and since this is one of the least easily changed features of the system, there is a problem of how to utilise it to the full in an economic manner.

The simplest way probably is by means of the well-known, but little used, principle of buffer storage at each human processing station. Items of work feed into a standing queue, and the operative draws work only from this queue. The operative's mean rate of working would then be the correct rate at which to feed the store, and it would also be the rate of output of the system. At the same time an extra degree of control in balancing a line would be provided, since the need for fractional operatives could largely be met by tolerances in the permitted rate of queue growth.

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PLASTICS – MOULDING AND FORMING PROCESSES

by G. T. SPENCE, A.M.I.Prod.E.*

Presented to the Liverpool Section of the Institution, 21st October, 1953.

THE field of plastics has widened to such a great extent in the last 15—20 years that to deal with all the processes involved in the manufacture of plastics, from the making of the material itself to the use and application of plastics, would create sufficient subject matter for several Papers.

In this talk I propose to confine the subject to the processes of moulding and forming of plastics and will only refer to the raw materials insofar as they affect these processes.

Application and Use.

To explain why we have so many different processes in the moulding of plastics, we have only to think of the variety of plastic materials available and of the variety of applications of these materials.

In the domestic field we have articles of table-ware such as cups, saucers, trays, cruet sets, cooking utensils such as colanders, pressure cooker parts; furniture, for example coffee tables; wireless sets; and there are many other applications.

Plastic materials are used in all types of industry, from the electrical industry where millions of plastic components are used every year, to the refrigeration industry where, in addition to the more common type of plastic article, door linings of formed laminates and sheets are replacing steel.

In the last few years, many additional fields have been opened to the use of plastics, with the advent of glass fibre, or glass-filled mouldings.

Materials

To assist you in following my descriptions of the moulding and forming processes, I feel that it is advisable for me to mention briefly the many classes of material which are used.

These can be grouped, for our purpose, into five classes:

(1) thermosetting moulding powders;
(2) thermoplastic moulding powders;
(3) thermoplastic sheet;
(4) thermosetting laminates;
(5) low pressure glass fibre mouldings and laminates.

(1) A *Thermosetting Material* is composed basically of a thermosetting resin, a filler, and a catalyst, which assists the chemical reaction of the resin. During moulding under the action of heat and pressure, the resin is chemically transformed from its secondary unstable form to its final stable form, after which it is almost inert.

The four most common resins of this type are urea, melamine, phenol and cresylic.

Urea and melamine are used primarily for decoration and domestic use, the fillers used being paper on wood.

Phenol and, to a much lesser degree, cresylic are used very extensively for industrial applications. A larger variety of materials is available with these resins, as the variety of fillers, which give the material most of its properties, is much greater.

For general purpose work the filler used is wood flour, but where special qualities are desirable such fillers as mica, for improved electrical properties; asbestos, for improved heat resistance; graphite, for improved bearing lubrication; rag or fabric, for improved strength and shock-resistant properties, can be used.

The employment of these different fillers, in addition to affecting the mechanical properties, also affects the moulding properties, hence the choice of process and method of mould design.

(2) A *Thermoplastic Material* consists basically of a thermoplastic polymer together with a plasticiser. The former is the organic molecule, the latter being added to assist these molecules to slide over each other during moulding, thus affecting the flow properties of the material.

During the moulding of thermoplastics a physical change only takes place, which is reversible, so that material moulded can be broken up, remelted and remoulded.

Materials in this category are cellulose acetate, butyrate, styrene, diakon (methyl methacrylate), polyvinyl chloride, nylon, ethyl cellulose, alkathene.

* Tools Manager and Chief Draughtsman, Ashdowns, Ltd., St. Helens.

(3) ***Thermoplastic Sheet*** has, of course, the same physical and chemical properties as its powder counterpart, but when used as raw material in the sheet form lends itself readily for use in cheaper forming methods.

The chief materials used in this form are methyl methacrylate, this time known as "Perspex", in the form of cast sheets, and polyvinyl chloride supplied in calendered sheet.

(4) ***Thermosetting High Pressure Laminates*** consist, as with other plastic materials, of a synthetic resin with a filler, but with these the filler is in sheet form, and the method of manufacture is to impregnate the filler with the resin. Resins used are phenol, cresylic, urea and melamine. Fillers employed are paper and fabric of various grades.

(5) ***Materials for Low Pressure Mouldings or Laminates*** consist usually of a glass filler impregnated with a resin.

The glass filler can be in any of several forms, the more common being cloth, mat or yarn, depending largely on the process used.

Several types of resin may be used, depending on the properties required and the forming process used. Most common are silicone resin which is very expensive, and is used where high heat resistance is required, and polyester resin, of which many grades are available.

Processes

From the outline I have given of the materials used in the forming of plastics, although I have only briefly mentioned the subject, it will be readily understood that the choice of process to be used is primarily decided by the material which is selected for the job. It is obvious I think, that, for example, thermosetting and thermoplastic moulding powders cannot, with their radically different physical and chemical qualities and properties, be moulded by the same method. Also, that thermoplastic sheet, will lend itself to forming, rather than moulding, and that the methods required to form it will be different from those required to form high pressure formed laminates, the method for which is more akin to the moulding process.

Generally speaking, the processes used can be related to the materials, hence the reason for my special grouping, earlier, of the materials used, but in special cases the whole or part of a process used for one class of material, can and is adopted in the manufacture of material of another class. I am, hence, only reviewing the normal processes.

The most common process used in the manufacture of plastic components is the moulding process, it being used both for thermosetting and thermoplastics material, although the methods used are different. I will consider first this process, dealing with the moulding of thermosetting materials formerly known as bakelite, and then following on with the moulding of the thermoplastics.

Thermosetting Material Moulding Processes

There are three methods commonly used in the moulding of thermosetting materials:

(a) compression, which is the original method;

(b) transfer;

(c) plunger or independent transfer.

As mentioned previously, the choice is largely influenced by the material used, but other factors also have to be considered. For instance, where inserts have to be moulded in the component it is often advisable to use a transfer mould technique rather than a normal compression method; on the other hand, the shape of certain components rule out the use of the transfer process and warrant the use of the compression process.

During the moulding process the material is placed under pressure and heat, and initially behaves for approximately 10 to 40 seconds as a fluid of high viscosity, until the chemical reaction has advanced to the stage where the resin becomes solid again, and then under continual action of heat and pressure, the chemical action will eventually be completed.

The length of time required for the chemical reaction is referred to as the "baking" or "cure" time, and the length of time that the material remains in the same fluid state is referred to as one of the flow properties of a material.

Both these vary according to the catalyst used, the lubricant in the material, the type of resin, and the type of filler. The variations of this phenomenon largely influence the choice of method, the pressure used and the temperatures.

Preheating

To assist in reducing this "cure" time, material is very often preheated almost to baking temperature before it is applied to the mould; this tends to soften the material and allows pressure to be applied more quickly, avoiding any delay in the material having to pick up heat from the mould to bring it to this soft state.

Methods employed are:

(1) heating in hot air (gas or dry steam);

(2) heating with steam, although this reduces the strength and gives inferior surface finish;

(3) high frequency resistance heating. This is by far the best method, as the material is heated more uniformly and quickly. Its chief disadvantage is high capital and running cost.

Pelleting

Material is applied to the moulds, directly or indirectly, in either powder form or pellet or tablet form.

In powder form each charge is weighed accurately and is applied to the mould either in the cold or preheated condition.

Where material is loaded in the pellet form, weighing is usually unnecessary, as the pellets are

produced on tableting machines to a reasonable degree of accuracy in weight. These tableting machines compress the material cold with a ratio of from 2—1, depending on the bulk factor of the material, the weight being obtained by volume capacity of the cavity.

Chief advantages of loading in the pellet form are that it:

(1) saves weighing operations;

(2) facilitates the use of preheating;

(3) eases the method of loading material in the mould, particularly with moulds such as car window frames.

Unfortunately, some materials of high bulk ratio cannot be pelleted.

Moulds

Moulds used for moulding thermosetting materials have to withstand pressure from one ton per sq. in. to, in exceptional circumstances, 10 tons per sq. in.; resist abrasion during flow, particularly with mineral type filled mouldings; be capable of being polished and maintaining that polish; and be hard enough to withstand bearing one with the other to give correct location. For these reasons steels of 3—4% nickel/1—1.5% chromium, with a small amount of molybdenum, are used.

To overcome the tendency of some materials to stain the mould, chromium plating of moulding surfaces is employed. Designs can vary from the simple two-piece punch and die type as would be necessary to produce a simple beaker (Fig. 1), to those complicated moulds necessary to produce such articles as meter cases, where loose pads or splits are employed to mould undercuts or back tapers on the article. Also, moulds may be single impression, or designed to produce 20—40, or even 100, per drop.

So far I have dealt with items which are common to all methods of moulding thermosetting plastic materials. Now let us consider the actual methods.

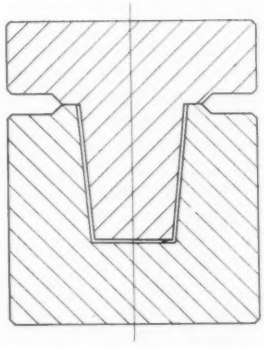

Fig. 1. Simple beaker mould

Compression Method

This consists of having two or more forces, one usually known as the punch unit and the other as the die unit. Both are formed or built up so that when closed a cavity exists between the two, which is the same shape and size of the component required plus the appropriate shrinkage. Allowances on average are .006″ per inch (varying with material).

Provision is made to locate the units accurately together to register before pressure is applied. Sufficient volume must be provided in the mould to allow for the loading of the material either in powder or pellet form.

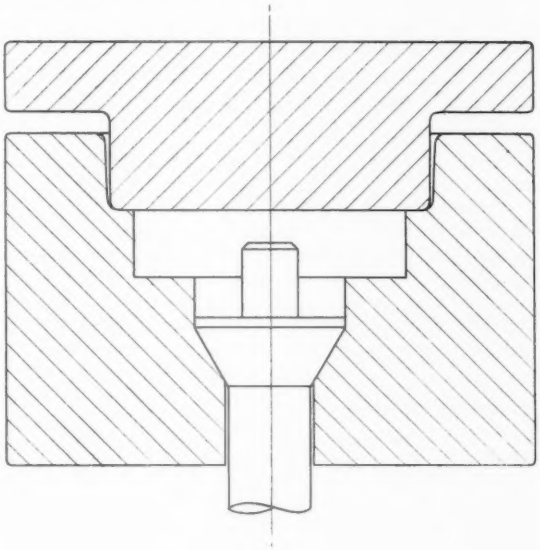

Fig. 2

Fig. 2 shows a simple article to be produced which has a convenient shoulder, which will provide a good trimming edge at the parting line where the punch and die units meet. With this method a little extra material, over the weight of the component, is added, to ensure complete filling of cavity, and under pressure this is squeezed out and partially trapped between the "meeting" or "land" faces of the mould, creating a "fin", "flash" or "spew" which has to be removed after moulding.

Moulding is carried out on a standard hydraulic press. In this method one unit is secured to the top table of the press, the other to the bottom, and provision made to heat the moulds up to temperatures varying from 275°F.—325°F., depending on material. Urea and melamine are heated to approximately 280°C., and phenol to 300°—320°C. The material is loaded in the bottom unit and the pressure applied on closing the press. The material is allowed to flow, to fill the cavity, when the extra weight will be squeezed out, and then baked for 2—6 minutes, depending on the material used and the section of the component. On completion of baking, the press is opened and the component is blown, or mechanically ejected by

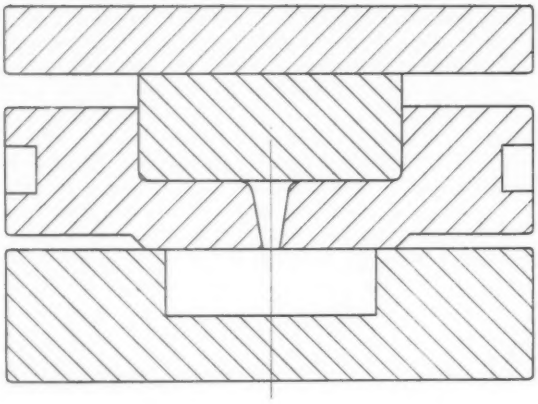

Fig. 3. Typical set-up for transfer moulding

small pins, from one of the units, either punch or die.

Pressure used depends again on the type of material moulded. Phenol material may require from 1 ton/sq. in. for wood filled material to 3—4 tons/sq. in. for high shock-resistant material. Urea material and melamine may require from 2—5 tons/sq. in. Depth of draw of component also affects the pressure required.

Transfer Method

Due to the mould being loaded in the open position and, hence, the production of "flash" by the compression method, a later method was developed known as the transfer process. In this method the mould parts forming the cavity are closed, and the load is applied in a separate loading chamber. On the application of pressure the load is transferred through a feed orifice from the loading chamber into the mould cavity, the latter being held closed by the same pressure force, which is being employed to effect the transfer. This method is very satisfactory, as no flash or spew is created at the parting line of the mould, provided the balance of hydraulic pressure is maintained or, in other words, the projected area of the cavity is kept below the area of the loading or transfer chamber.

Fig. 3 shows a typical set-up for transfer moulding. The punch unit with backplate for fixing is secured to the top plate of the press. The loading chamber or pot is slung on rails, which are supported from the press, but is free to move with the moving table of the press. Underneath the pot is fixed the top half of the mould, the bottom half being secured to the bottom table of the press.

Heating is provided to all parts of the set-up, punch, pot and mould, to give uniform heating.

After the load has been applied, the press is closed and, in closing, the mould is closed first by the initial movement of the press, and then as the press continues its stroke, the punch is pushed into the pot which forces the material through the small feed orifice into the mould, and afterwards maintains pressure on the material to prevent any flow back of material. Sufficient material is loaded so that after filling the mould cavity some is left in the pot. This ensures that follow-up pressure can be maintained during the "curing period".

When the cure is completed, the press is opened, the feed breaks, and the moulding which sticks in the bottom half of the mould is ejected in the same manner as used in compression moulding. The feed is drawn out on to the punch by some undercut or sharp thread and is then quickly removed from the punch.

The process is used for both single and multi-impression tools. The size of the feed is determined as a function of the weight of load, the pressure used, and the type of material used.

While urea and melamine are moulded by this process, it is more commonly used for the phenolic-based material. It will be readily recognised that flow properties of the material are most important when this type, and the next process I shall speak of, are employed. This process is carried out on a standard hydraulic press, similar to the ones used for the compression process.

Plunger or Independent Transfer Process

While the normal transfer process for certain classes of mouldings was a great improvement on the compression process, both in speed and quality, the material had still to be loaded with the press in the open position, and time was spent in closing the press slowly to locate the two halves of the tool and then the pot with the punch. To increase production, the plunger or independent transfer process was developed, a typical example of which is shown in Fig. 4.

The principle of this process is similar to that of the normal transfer process in that material is transferred from a pot to the mould cavity, but in this case the transfer force is supplied by a separate ram powered from an independent ram unit, located at the top of the press. The bottom half of the tool is fixed to the upstroking bottom table of the press, and the top half to the fixed table at the top of the press. The top half of the mould houses the loading or transfer pot and the transfer ram moves through the top of the press into the pot. Provision is made for loading the pot by inserting a "letter box" plate between the top half of the tool and the press table, this plate having a slot cut in from the front leading to the pot, so that material in preheated pellet form can be loaded in the press after the mould has been closed on the main ram of the press. The material is then transferred under the action of the transfer ram. As with the normal transfer method, temperatures used are similar to those used in the compression process.

With this process, as two external power units are working independently, it is necessary to keep within the hydraulic balance of pressures, otherwise the mould will open during the period of transfer. To avoid this, the total of the projected area of the mouldings, plus the projected areas of the

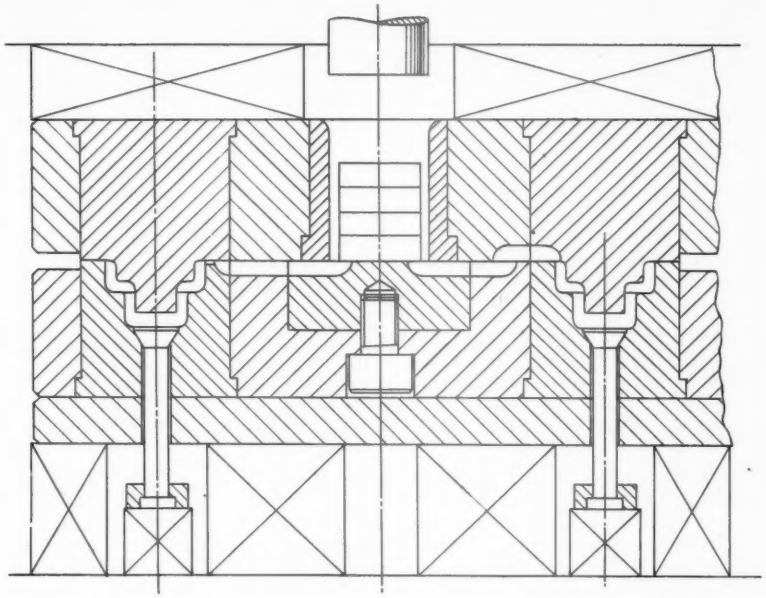

Fig. 4
Plunger or independent transfer process

runners and culls, when multiplied by the pressure on the plunger in tons per sq. in. should never equal the clamping force on the tool, that is, the force exerted by the main ram of the press.

Should the balance be exceeded the mould would open and material would escape between the surface of the mould.

The pressures used in plunger or transfer moulding are the subject of dispute and discussion throughout the industry. I feel, however, that pressures of 4 tons/sq. in. for general purpose phenol material; 6/8 tons/sq. in. for high shock-resisting phenol material; and 8/12 tons/sq. in. for urea and melamine materials should prove satisfactory.

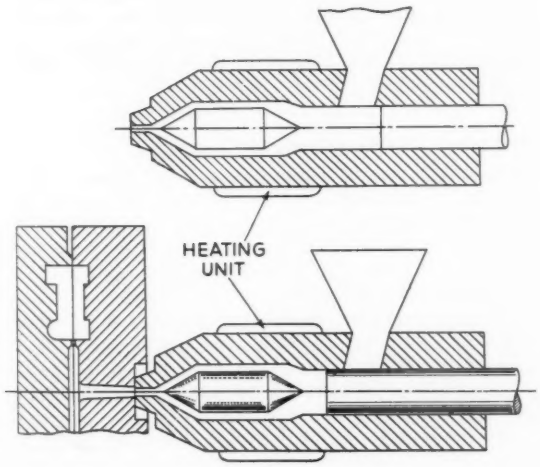

Fig. 5

Thermoplastic Material Moulding Processes

Thermoplastic materials are moulded by a process known as the injection process, except for special application where compression or transfer, or the extrusion process, is employed.

The treatment of thermoplastics is in many ways the reverse of that given to thermosetting materials. With thermosetting materials the mould is heated and the material virtually cold when loaded into the mould and during moulding is given a baking or curing time. With thermoplastics the mould is kept cool, the material is forced into the mould cavity hot, and a cooling period has to be allowed.

For the above reasons, machines used are different radically from the normal hydraulic press. They consist basically of two units:

(a) the injection cylinder, where the material is loaded and heated, and from which the mould cavity is filled;

(b) the clamping unit, which operates the movement of the mould and ejection.

In operation, the cylinder is loaded automatically with a measured amount of material on the return stroke of the injection ram. The cylinder is heated electrically and transfers heat to the material up to temperatures between 220°—300° dependent on the material being used. Inside the cylinder, to assist in obtaining a uniformity of heat, a torpedo spreader is fitted, as in Fig. 5. The cylinder is large enough to contain 5—6 times the volume which the ram can displace at one stroke. At the end of the cylinder is fitted a nozzle, through which the material is fed into the mould.

When moulding temperatures are reached, the mould is closed by the clamping force and under

pressure of 9—10 tons from the injection ram, molten material is shot from the cylinder, through the nozzle which seats against a feed orifice in the tool, through the feed, along runners into the cavities. The cavities having been filled, the injection ram is dwelled for a few seconds, after which it is returned, cooling is continued, the time depending on the section, and then the machine is opened and the moulding extracted.

This process is usually semi-automatic. The machine sizes are governed by the weight per shot they will shoot of cellulose acetate. For requirements of weight shot of other material it is necessary to convert, according to their specific gravity.

Ram pressures used are dependent on the materials used, and the feeds and runners on the size of the moulding. For C. A. styrene, nylon, alkathene, ram pressures varying from 5—9 tons may be used; for diakon it is usual to increase to 14/16 tons/sq. in.

The process lends itself to the use of multi-impression tools, the limit being the maximum weight of shot and the hydraulic balance between the opening force and the clamping force. Speeds attainable by the injection process are much greater than those used in the thermosetting process, 25 to 45 seconds being average.

Injection moulds are usually made from nickel chrome steels and are very often plated. They are, however, frequently left unhardened. Brass and beryllium copper moulds are also used.

C.A. styrene, alkathene, butyrate and diakon are all moulded in a similar manner but with P.V.C. special treatment has to be given, as hydrochloric acid gas is generated, which is harmful to the operator and the equipment. Also, with nylon, which has a sharp melting point and very low viscosity, precautions have to be taken to prevent dripping of the material from the cylinder nozzle.

Compression Moulding of Thermoplastic Material

In the injection process, due to stresses set up during moulding, strain is present in the finished mouldings. For normal applications this is not worth worrying about, but where strain is most objectionable in some instances the compression moulding technique is used.

This is rather a long and expensive process, taking on average a 20—30-minute cycle as against a 20—40-second cycle with the injection process.

It consists of heating the mould to moulding temperature, loading the material which has been preheated almost to moulding temperature, and then cooling the mould down until the material has cooled and hardened sufficiently to allow extraction. Then the mould has to be reheated for the next cycle. It can be clearly seen how costly this process can be.

Extrusion

This is the process applied to form rods, tubes, straps, etc., of varying length up to 100, 200, or 1,000 feet. An extrusion machine is used, into which material is fed through a hopper on to a worm screw rotating inside a cylinder. The cylinder is heated, and the worm screw varies either in pitch or depth of worm form to give a compression ratio which builds up a pressure on the material and forces it through a die of the required form mounted at the end of the cylinder. The take-off gear is in the form of a conveyor and the material, on being extracted from the die, is allowed to cool off and is sawn off to lengths or wound on a drum.

The most common materials used for this process are P.V.C., alkathene, and nylon.

High Pressure Thermosetting Laminate Moulding Processes

High pressure laminates are produced in several ways, the two most common being:
(a) the long or slow cycle method and (b) the hot moulding method.

(a) The slow cycle method is applied more to the moulding of flat sheets. It entails loading the material between plates, heating the press to moulding temperatures, curing or baking and then cooling down to a low temperature while the pressure is still held. This technique ensures that sheets produced are flat. As the cycle takes between 3/4 hours, multi-daylight presses are employed so that a large number of sheets are produced at one pressing. Thicknesses up to 4″ can be moulded.

(b) In the hot pressing process, formed sheets or flat sheets can be produced at faster cycles of 5 minutes for sections up to 100″. For sections above that the cycles are increased until at sections above ¼″, the process is not too satisfactory.

In this process steel tools are made to the correct form, the top tool making up with the bottom to within .010″. The material in sheet form, i.e., paper or fabric impregnated resin, is loaded on the tool and pressure applied.

Temperatures for moulding thermosetting laminates compare closely to those used for moulding phenol, urea and melamine, but pressures are considerably less being in the region of 1,000—2,000 lbs./sq. in.

Forming Thermoplastic Sheet

The forming of "Perspex" or P.V.C. sheet, which are the most common used, does not involve the high pressures of moulding. Hence, air pressure only is employed and hardwood or low pressure alloys form the basic materials from which the forming tools are made.

Forming may be carried out on male and female former set-up, but in many cases only one former is used, either male or female, to give the correct shape of the component, the actual forming being effected by air pressure or vacuum.

No matter how the forming is performed, the sheet is first heated in an oven until it is pliable and then, when applied to the former, is held by

a clamping ring before forming takes place. The forming operation takes seconds only, after which the material is held under pressure from 5—20 minutes to cool down. A typical mould is illustrated in Fig. 6.

Sheets for forming can be obtained in sections from 1/32″—¼″.

Quite a considerable amount of fabrication is performed from parts formed of "Perspex", which can be cemented together easily and shows very little sign of cemented joints.

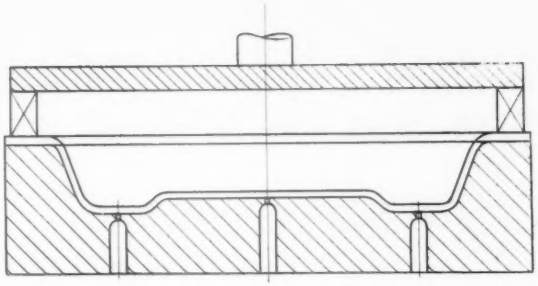

Fig. 6

Moulding of Low Pressure Mouldings and Laminates

The production of low pressure mouldings and laminates incorporating a glass fibre filler is the most recent development in the plastics industry.

Glass is used in many forms, cloth, mat and yarn being the most common, and several types of resin are used with the glass, dependent on the process used. Pressures used vary from 2—100 lbs./sq. in. which, when compared with other processes, are very small.

There are many techniques used in the forming of articles from these materials, the most common being:

(a) laying up, where the glass is wrapped round a male former, or inside a female former and impregnated by hand;

(b) winding, where tubes, etc., can be made by winding cloth or yarn round a mandrel, the resin being applied during the winding process;

(c) pressing of flat sheet hydraulically after the glass cloth or mat has been impregnated with resin. This is similar to the moulding of laminates, except that pressures are much lower;

(d) moulding of forms using chopped fibres preformed to the required shape and then moulded in a male and female tool after resin has been applied, similar to a compression type of mould.

Conclusion

In conclusion, the moulds are not the final answer. There is the "technique" and "know how" which is essential to make these moulds produce goods to the required standards, and whilst plastic mouldings of any description may appear to be reasonable in cost, the moulds are the first, and most important essential. Good moulds can be very expensive. Here we have only spoken about the moulds necessary to produce components in the many differing materials commonly used in the trade, and their various methods of manufacture.

"Design and Operation of Oil Fired Furnaces" (concluded from page 555).

So far as low pressure air burners are concerned—and they are the most common ones in use—it is also very necessary that the fan supplying the air supplies the correct amount at the correct water gauge pressure for the particular burner being used (pressure may be from 7″ to 30″ depending on the design of the burner).

The arrangement of the oil supply is also important, insofar as adequate means must be provided in the form of filters to prevent any foreign particles or sludge getting to the burner and thus interfering with its operation through fully or partially choking the oil passages, and so causing bad atomisation and uneven flame envelope. Also the head of oil, whether by gravity or pump, must be sufficient to push the oil through the burner adequately overcoming all resistance to its flow. Furthermore, the pipe sizes and oil pressures must be adequate in installations where more than one burner is operating from the system so that operation of one burner does not upset that of another.

I would reiterate that atomisation is highly important to successful and economical burner operation.

Acknowledgments

The Shell Co. of Australia Ltd., Adelaide, for permission to present the Paper.

British Tube Mills (Aust.) Pty. Ltd., for permission to reproduce Fig. 18.

The publication, "Practical Industrial Furnace Design", by Mawhinney, from which most of the illustrations and tables were taken, and certain of the information included in the Paper.

C.M.A. ANNUAL CONFERENCE

The Fourth Annual One-Day Conference of the Office Management Association will be held in Glasgow on Tuesday, 12th October, 1954.

The subject of this year's Conference is "Sales Accounting and Analysis", and the chief speaker will be Mr. G. E. Ellard, A.C.W.A., of the Power Gas Corporation, Stockton-on-Tees. There will also be an exhibition of office machinery and equipment appropriate to the subject of the Conference.

THE USE OF BORON STEELS

by R. WILCOCK.*

READERS of metallurgical publications, particularly those originating in the United States, cannot be unaware of the interest shown in that country in boron steels. The use of these steels has been at the head of the drive for the conservation of alloying elements in short supply; most attention has been paid to replacing nickel and molybdenum, although some metallurgists regard it as a partial substitute for manganese in case of real emergency.

The questions then arise, what are these boron steels and how do they differ from conventional alloys? How are they made, and what does the boron do? In this Paper we will try to answer these questions.

A boron treated steel is one to which an addition of 0.002/0.005% boron has been made, that is roughly 1 to 2 ozs. per ton. Less than this amount is ineffective: more does not give any greater effectiveness and could in fact lead to difficulties in the hot working of the steel. Therefore, unlike normal alloying elements which can be varied in amount—as with say nickel from ½% to 5% in ordinary structural steels—there is only one range used. In effect we have only two variants: either a steel is boron treated or it is not.

Given the chance, boron will react with the oxygen and nitrogen present in the steel and will either be lost, or occur in an effective form. To prevent this, the boron is protected from absorbing these elements by alloys such as titanium, aluminium and silicon which have a greater affinity for them than has the boron. In point of fact, it is usually necessary to add 10 to 15 times as much of both aluminium and titanium as of boron; this addition can be made as ordinary ferro-alloys, but is more usually done by means of complex alloys. These contain the right proportions of silicon, titanium, aluminium and boron, and some of them also include vanadium and zirconium.

These additions are usually made to the ladle, but have at times been made to the mould. Because of the large amounts of deoxidents added to the boron, this treatment automatically makes the steel controlled to a fine grain size.

What does the boron do? Some years ago rather extravagant claims were made for boron treatment, but nowadays only one major claim is made—that it increases hardenability and, thereby, can be used to replace other alloys such as manganese, nickel, chromium and molybdenum. The A.S.M. handbook describes the role of boron in steels as follows: "Boron is used in steel for one purpose only—to increase the hardenability, that is, to increase the depth to which a steel will harden when quenched."

Boron steels are peculiar in that, at approximately the eutectoid composition, boron appears to have little or no effect on hardenability. However, as the carbon decreases below the eutectoid composition, the effectiveness of boron increases linearly. Because of this boron steels have found little or no application in case-hardening steels where, of course, the case is built up in carbon content to eutectoid or hypereutectoid compositions.

One point that follows is that to obtain the improvements in mechanical properties with the addition of boron, these steels must be used in the quenched and tempered condition: with one exception, which will be mentioned later, there are no advantages to be obtained in the normalised or annealed conditions. This is illustrated in Table I.

Table I

1½% MANGANESE STEEL (EN. 15)

Boron or No Boron (NB or B)	Ultimate Stress tons/sq. in.
Annealed 750°C. ⅝ in. dia.	
NB	35.8
B	35.7
Normalised 850°C. 1½ in. dia.	
NB	47.9
B	47.1

Jominy End-Quench Hardenability Test

The increased hardenability can be shown more graphically by the use of the end-quench test, which was devised in the United States by Jominy.

This test consists of water quenching one end of a cylindrical test specimen 1" in diameter and

*Samuel Fox & Co. Ltd., Sheffield.

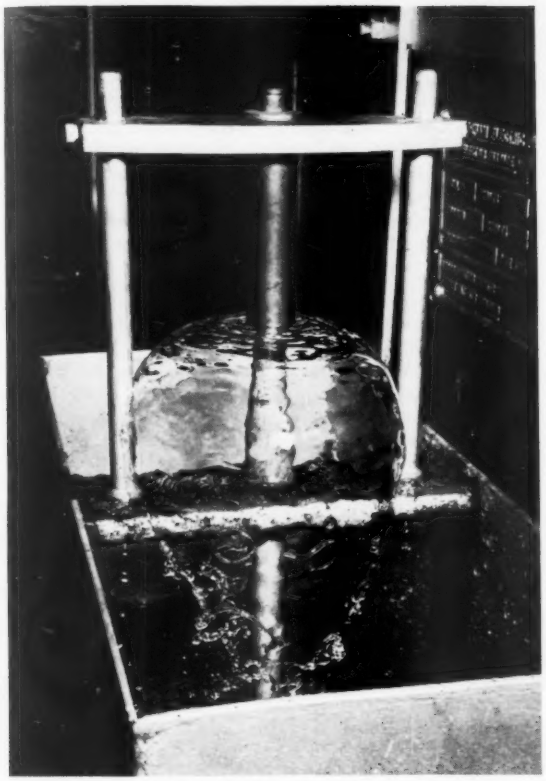

Fig. 1. End quenching a Jominy test-piece.

measuring the hardness at various distances from the quenched end. The sample is heated to the quenching temperature appropriate to its composition, taking precautions to prevent scaling and decarburisation. After suitable soaking the specimen is swiftly transferred to a quenching jig, which holds it vertically over a controlled water jet which quenches the end of the specimen. The water is allowed to flow until the sample is practically cold. A picture of the Jominy rig is shown in Fig. 1.

Smooth, flat surfaces are then ground 0.015" deep lengthwise, on opposite sides of the samples, these flats then being polished. Vickers or Rockwell hardness tests are then obtained at $\frac{1}{8}$" or 1/10" intervals along the length of the flat surfaces.

The rate of quenching is very fast on the end but, as the heat must pass through the sample by conduction, the rate diminishes as the distance from the end increases, being very slow at the top end of the test piece. Thus, in one sample a quenching-rate gradient is obtained and the hardness tests give a corresponding hardness gradient.

Different steels will show different hardness gradients and, therefore, many useful deductions can be made from the Jominy curves. Laboratory experiments have related these curves to the cooling rates of various sized bars, quenching in either water

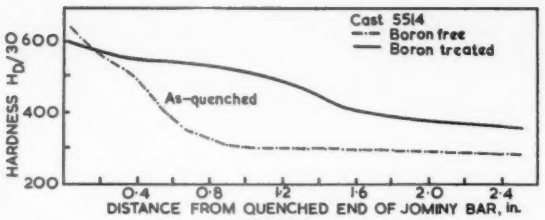

Fig. 2

or oil, and so to some extent a study of the Jominy curves can give an indication of the maximum sizes in which a certain steel can be treated to give adequate hardening.

Fig. 2 shows two Jominy curves, both of the same steel—a manganese-molybdenum steel of analysis:

	(NB) %	(B) %
Carbon - - -	0.35	0.33
Manganese - -	1.44	1.44
Nickel - - -	0.14	0.15
Chromium - -	0.07	0.06
Molybdenum - -	0.28	0.28
Boron (Total) - -	0.0002	0.0036

One ingot was produced normally, and the other was as nearly as possibly identical except for the presence of 0.0036% boron. The difference in the curves, however, is obvious. It can be seen that the boron steel maintains a given arbitrary hardness level—say 500 diamond hardness—to a greater distance from the quenched end. In effect, it will harden fully in a bigger section than will the untreated steel. Fig. 3 shows hardness traverses of bars of various sizes in the oil quenched condition, indicating very clearly the greater degree of hardening achieved by the boron steel.

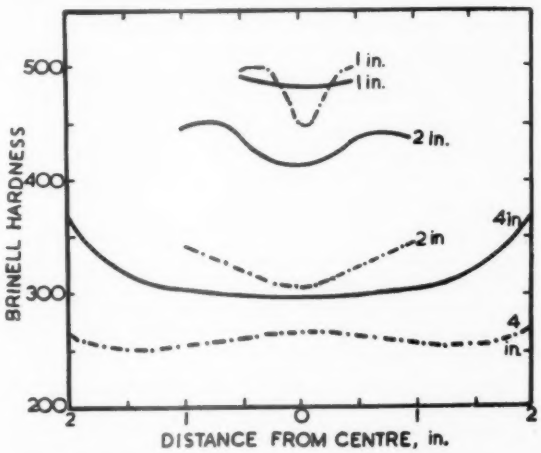

Fig. 3. Hardness traverses on boron-free and boron-treated manganese-molybdenum steel. (- - -. boron-free; —— boron-treated).

It can be calculated from the Jominy curves that this particular steel when boron treated will harden fully up to 2½" diameter, but without boron the maximum size for full hardening is 1.05" diameter. This is known to the metallurgist as mass effect. Table II shows the effect of boron treating a number of steels and the corresponding maximum sizes at which full hardening can be achieved.

Table II

LIMITING SIZE TO GIVE FULL HARDENING AS CALCULATED FROM JOMINY CURVES

Cast	Type of Steel	Bar Dia. in.	
		Boron Free	Boron Treated
5380	1½% Mn. 0.03% Mo.	0.45	1.2
5513	1½% Mn. 0.11% Mo.	0.5	1.9
5609	1½% Mn. 0.20% Mo.	0.8	2.5
5514	1½% Mn. 0.28% Mo.	1.05	2.7
5382	½% Ni., Cr., Mo.	1.05	2.5

In effect, this means that by an addition of boron, a steel can be upgraded—it can be made to give mechanical properties otherwise obtained only in a more highly alloyed steel. In sizes where full hardening can be achieved there are no disadvantages in using boron steels—in mechanical properties, they are virtually identical with the more highly alloyed steels which they replace. The only snag is the economic one that the boron addition is likely to cost about the same as the nickel or molybdenum that it replaces, so that there would be little saving achieved there; and now that these alloys are in better supply, the urgency in conserving them has diminished. However, if shortages again occur, boron treatment is a factor that we cannot afford to ignore.

Table III indicates the way in which boron improves the tensile strength for a similar heat-treatment. Generally it increases the tensile but decreases the impact, though not seriously.

In heat treatment it is usual to avoid tempering in certain ranges below about 500°C. because of the danger of temper-brittleness. Taking this factor into consideration, it follows that a boron steel can be treated to a tensile level that would otherwise call for a more highly alloyed steel.

Table IV shows up one of the disadvantages of boron treatment. When, because of mass effect, a steel is not fully hardened—as for example any of those quoted in Table IV in 4" square—there still might be some advantage in ultimate stress, but the impact suffers, often very badly.

Because of this fall-off in impact, when dealing with British specifications, the use of boron is strictly limited, as these specifications usually insist on fairly high impact properties. It is in this respect that the United States approach differs from ours. Many of the users have largely disregarded impact and have substituted boron steels on the basis of equal hardenability, irrespective of size. I am not going to say which is the right attitude—that is the task of an engineer rather than that of a metallurgist—but it is evident that at any rate in some cases the American approach is worth considering.

That, however, is a wider field than a discussion on boron in itself merits, for if that attitude is right, there are many applications where lower alloy steels without any boron treatment could give equal tensile strengths, but poorer impact properties, than those steels at present being used. And there are many other cases where the factor of ignorance prompts the use of a safe material and leads to the use of a more highly alloyed (and more expensive) steel than is really necessary.

Fortiweld

It has been shown that there is no advantage in the use of boron in any but the quenched and quenched and tempered conditions. There now remains, however, the exception to that general statement. This is a carbon-molybdenum-boron steel known as Fortiweld, which gives a marked improvement over the same steel without boron in the normalised or as-rolled conditions.

Table III

MANGANESE-MOLYBDENUM STEEL (EN. 16)

Size, in.	Boron or No Boron	Ultimate stress tons/sq. in.	Izod Impact ft. lb.
Tempered 500°C.			
1⅛	NB	65.2	59
	B	72.8	53
2½	NB	57.2	69
	B	65.6	37
Tempered 600°C.			
1⅛	NB	57.9	72
	B	64.6	56
2½	NB	52.8	79
	B	58.1	63

If, however, different tempering temperatures are used to equalise the tensiles, the impacts are similarly equalised. This is illustrated in Table IV.

TABLE IV

IZOD-IMPACT VALUES OF MN-MO STEELS FOR EQUAL ULTIMATE STRESS

Effect of Boron, Molybdenum, and Size Oil-quenched 850°C., tempered 550°C.

Size, in.			1½		2		2½		4	
Cast	Mo.%	Boron (B) or No Boron (NB)	Ultimate stress tons/sq. in.	Izod Impact ft. lb.	Ultimate stress tons/sq. in.	Izod Impact ft. lb.	Ultimate stress tons/sq. in.	Izod Impact ft. lb.	Ultimate stress tons/ q. in.	Izod Impact ft. lb.
5380	0.03	NB	52.3	77	51.4	81	51.4	72	51.0	71
		B	56.8*	75	53.2	34	50.3	41	48.6	24
5513	0.11	NB	52.9	79	49.4	85	49.9	79	48.0	63
		B	56.4*	71	49.8*	69	51.9	37	49.2	29
5609	0.20	NB	59.2	52	56.0	58	57.6	61	56.0	29
		B	63.7*	66	60.8*	55	57.4*	48	57.8	16
5514	0.28	NB	65.2	59	58.1	69	57.2	69	58.6	44
		B	64.6*	56	60.8*	65	58.1*	63	59.1	28

* Tempered at 600°C.

There is a growing appreciation of this type of structural steel which can give excellent properties without expensive treatments. The fact that without sacrificing the properties many different operations, such as welding and hot fabrication, can be done on the site or on big structures where subsequent heat treatment is virtually impossible, makes this a particularly valuable steel.

Applications for Boron Steels

Apart from Fortiweld, which because of its unique properties is finding considerable use in a wide variety of applications ranging from heavy structures to aircraft, boron steels have, for all practical purposes, not been used in this country. On the other hand, however, over 700,000 tons were produced in the United States in 1952—about 10% of the total alloy steels made. It will be useful then to consider the way in which this large tonnage was consumed and how these steels are used to replace the more traditional ones. To do so we must first try to understand the American attitude to substitution.

There is seldom an exact and complete substitute available, and whilst such factors as strength, hardenability and notch sensitivity can be evaluated with measurable degrees of accuracy, factors such as weldability, machinability and hot and cold formability are entirely qualitative and may be difficult to evaluate. Some of these qualitative factors can vary fairly widely for steels at the same hardness levels.

In spite of the recognition of these problems by leading American metallurgists they have been satisfied to substitute boron steels for other alloy qualities.

TABLE V

Quality :	½% Mo	½% Mo with Boron	Mild steel	Mild steel with Boron
%				
Carbon	0.09	0.08	0.09	0.08
Manganese	0.43	0.40	0.42	0.41
Silicon	0.25	0.25	0.25	0.26
Molybdenum	0.58	0.58	–	–
Boron	–	0.003	–	0.003
Mechanical Properties				
Material : ⅝" in dia. (forged) bar.				
Heat treatment : 930°C. A.C.				
Ultimate tensile stress tons/sq. in.	28.5	41.0	26.5	25.8
Yield stress tons sq. in.	16.2	34.8*	18.7	17.1
Elongation on $4\sqrt{A_o}$ per cent.	40.0	26.0	44.0	41.1
Reduction of area, per cent.	74.0	71.3	72.0	73.6
Izod impact value ft. lb.	99	93	94	96

* This corresponds to 1.0 per cent extension on 2 inches, no true yield stress existing.

mainly on the basis of equivalent Jominy hardenability. Even on this basis, exact equivalence of hardenability between the steel normally used and a substitute has not been considered essential, provided the hardenabilities of the two steels match for the size of the particular section being considered. Thus while there is a large amount of Jominy hardenability data on boron-containing alloy steels, information on tests more familiar to British metallurgists and engineers is much more restricted.

It is in this way that some rather extravagant ideas have arisen on what boron can do. Some of the steels previously used have for the ruling section involved, been more highly alloyed than necessary. For example, a 1½% nickel-chromium-molybdenum steel for axle shafts was replaced by a steel containing boron, but with less than ½% nickel and small amounts of chromium and molybdenum. This is a definite scaling down in the mechanical properties available in the centre of the shaft. But the engineer argues that in torsion the properties at the centre do not matter—there is no stress there. So he tries it, and it works.

It must be pointed out, however, that the American user industries are far better equipped than those in this country to carry out fatigue testing on complete components, where they can assess both the metallurgical and the engineering factors together. These testing facilities are extensively used and are a major factor in enabling them to make radical changes quickly, and without a great deal of risk of excessive subsequent service failures.

Another word of warning. It should not be assumed that, because in a particular application steel 'A' satisfactorily replaces steel 'B', the two steels are interchangeable in all circumstances.

There are many other uses to which these steels have been put where the saving of alloy has been less spectacular and where the properties of the steels have been similar in the ruling sections concerned. A short list of some of the major usages might be interesting : gears, axle shafts, oil drilling bits, engineer's hand tools, springs, steering knuckles, cold-head bolts.

This last application is one that illustrates a consequential saving. In, say, ½" diameter, a carbon-boron steel can be heat-treated to give properties very similar to those in a low alloy steel—say a manganese-molybdenum steel. But in the annealed condition it behaves like a carbon steel, not like the alloy steels it replaces. This means it will head better, or machine better, in the screw-cutting operation. If there are machining operations before treatment, there are some quite attractive potential savings to be made, not in the cost of the steels, but in higher throughput speeds and better tool life.

This help to productivity is possibly the property in boron steels that it will be most profitable to exploit; and it is an aspect that has had relatively little attention paid to it by the engineer, or for that matter, by the metallurgist, who has tended to think of it as a substitute alloy. Shortages of alloys come and go and bring their transient problems, but the problems of machining or cold-forming steels remain at all times with the production engineer. If therefore an ordinary alloy steel is being used for an application on which there is a good deal of machining, it might be worth considering whether a boron steel might not help.

Management Studies

The Department of Management Studies of The Polytechnic, Regent Street, London, W.1., is again offering during the coming session a number of part-time day courses of special interest and value to Office Managers, Accountants, Cost Accountants O. & M. Officers and others concerned primarily with the office or administration.

One of the courses, Work Simplification in the Office, deals with the improvement of clerical procedures through the application of the methods of work study to the office. It is essentially a practical course in which students have full opportunity of presenting their own procedures for simplification.

The course for Office Supervisors provides training in the theory and practice of supervision, and an optional revision course in Office Organisation and Method is included. More specialised shorter courses are offered in Form Design and Control, Management Accounting, Presentation of Information to Top Management, Commercial and Industrial Forecasting, and The Legal Background for Policy-making.

All the courses involve attendance on one morning or afternoon weekly or fortnightly. Full details may be obtained from The Registrar, The Department of Management Studies, St. Katharine's House, 194, Albany Street, N.W.1.

Production Exhibition Catalogues

A number of catalogues for the recent Production Exhibition at Olympia are still available, and may be obtained from the organisers, Andry Montgomery, Ltd., 11, Avenue Chambers, 4, Vernon Place, London, W.C.1., price 2/3d. each, including postage.

THE VALUE OF WORK STUDY TO INDUSTRY

by W. H. HODGETTS, M.I.Prod.E.*

Presented to the Birmingham Section of the Institution, 21st October, 1953.

BEFORE I attempt to give you my ideas of the value of Work Study to industry, I feel I must start by a simple reminder of the value and purposes of industry itself. In a welfare state people tend to forget that from industry and commerce must come all the means to feed, clothe and house us and the state's intervention is merely in the form of high level redistributor of the rewards of industry. Whatever the form of government, it remains a fact that no nation can for long consume more than it produces. The redistribution does not make the cake any bigger, rather the reverse. In fact the purpose of industry, despite the fog of war, rationing and controls, is not to find directly or indirectly comfortable jobs for a lot of people, but to provide the necessary goods and services at a minimum cost of materials and time and it can only exist as long as it can do the job efficiently and economically. Its purpose is to be efficient and in case any of you feel that there is no problem to solve because we have always been pretty good chaps and we get better every day, suppose we start the discussion by firing back some Work Study questions at the unnamed Work Study practitioners I am threatening to foist on you, such as:

(i) Is the operation of Work Study necessary?

(ii) Do I need it in my little works?

(iii) Must I have all the frills?

I will immediately set about answering the first question and the others will, I think, fall into place.

Why be bothered with the upset of introducing into our quiet work places yet another gang of so-called specialists? Why not leave well alone? We have got on quite well without it—why this sudden interest?

Comparison with American Methods

For my own part I am quite content to leave well alone if I can find something which I can truly describe as "well". What we, therefore, want to know at the beginning is, are we really satisfied with the general efficiency of the industry of our country? I suggest the only way to answer this question is to compare ourselves with what is admittedly the most efficient industrial nation in the world —the United States.

As far back as 1880 the general level of productivity of America, our main competitor, was slightly below our own. By 1890 it had caught up and since then it has increased by roughly 3% per annum, whereas our own has only increased by about 1½% per annum. The result is that to-day American productivity is more than double our own and the gap gets wider every year. The graph in Fig. 1 shows the two trends from 1880 and is carried forward to 1960 to illustrate how much worse will be our competitive position by that time if we do not take appropriate action.

Perhaps I should now define productivity, which is, in the sense that I have used it, that of the productivity of labour, i.e. the tons of steel, or the bales of linen produced per worker per year. You can, of course, have productivity of materials, of power, of plant, etc., in which productivity is a way of showing relative efficiency. But these are only helps towards our ultimate interest in the goods produced for the effort expended.

Labour productivity is the most important, since from "mine" to "shop", costs are mainly accumulated wages and salaries.

From the graph in Fig. 1, it is obvious that the gap between American and British labour productivity has existed for many years—widening each year. Why, therefore, did we only become nationally conscious of it after the War? In the first place it must be stressed that some industries in England are as efficient as their American counterparts. In fact, so far as fundamental research and development, and creation of new products, processes and plant are concerned, Britain compares very favourably with America. The difference, nevertheless, exists for two main reasons. One is that there are many

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THE EFFICIENCY GAP BEFORE TREATMENT

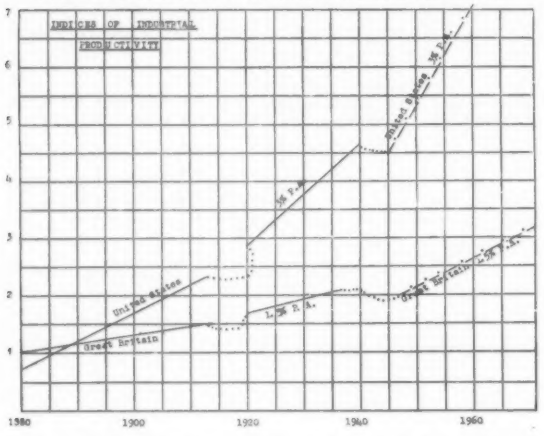

Fig. 1. Index of Productivity Common Level 1890/1

industries in Britain which are a long way behind their American counterparts, i.e., the disparity between the best and worst in Britain is much greater than between the best and worst in the States, and the other reason is that even where we have the right plant and process, we do not utilise them as intensively as they do. I shall say more about this later.

The fact that the problem only became generally recognised after the War was because between the Wars we supplemented our national income with the interest earned on our vast overseas investments, which themselves dated back to the days when we were as efficient as any other nation in the world. As you know, these investments had to be sold to pay part of the cost of the War. Even then the gap was hidden, first by Lease/Lend and then by Marshall Aid.

In consequence of these differences we are finding that as the sellers' market created by the War period is gradually overtaken, it is increasingly difficult for us to compete with the Americans in exports, and we have not yet felt the full impact of renewed German and Japanese competition.

What must we do to restore our competitive position?

By a curious coincidence, I.C.I. and the late Sir Stafford Cripps both set themselves the same target three years ago—namely a 10% increase in productivity *per annum* for five years in order to close appreciably the gap between our own and the American efficiency levels, and we have, in fact, already made considerable progress in this direction, but very much more remains to be done. We have now added to the graph (Fig. 2) a new line which shows the effect of the 10% per annum increase superimposed on the previous graph of the relative 'B' and 'A' productivity trends. This is obviously the solution—how do we achieve it? You will probably answer: "Get modern plant". This is not, however, the complete answer and in any case it would take a generation to re-equip all industry in this way.

CURRENT CONSIDERATIONS

Plant

In many of our industries we already have plant comparable with the best American plant, but there is a very definite limit to the rate at which modernisation and mechanisation can be justified and paid for. In my opinion there is a serious danger in Britain at the moment of over-capitalisation, particularly of heavy plant, including electricity generation. Too much expensive plant would increase rather than reduce costs. Acquiring modern plant is, in any case, only one step in the process of improvement of productivity. The next step is to use it.

Process

With its acquisition comes a very much increased need for ensuring that the process for which it was acquired, which must be the best of which it is capable, is in fact carried out consistently. In other words, steps towards standardisation of product and process to reduce changeovers are now much more essential.

Lay-out

The lay-out is of fundamental importance since modern plant is capable of processing very much bigger pieces; the old habit of running round the shop with the work in a truck is no longer possible, since you cannot have cranes running around in the same flexible way that a man can. The layout must, in fact, be designed to facilitate, so far as is humanly practicable, either a straight line flow with mechanical servicing between units, or batch production with rather different, but equally efficient, mechanical servicing between the stages. I am personally convinced that in many cases we have directed far too much of our attention to the isolated efficiency of the individual unit and practically no attention to the problems of flow from one unit to another, or of the acquisition of stores, lubricants and all the

THE EFFICIENCY GAP AFTER TREATMENT

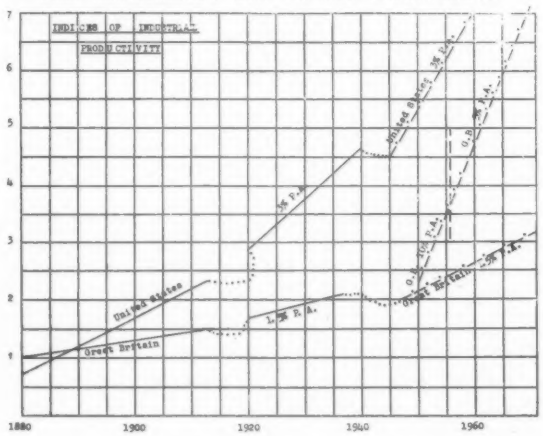

Fig. 2. Index of Productivity Common Level 1890/1

services which frequently have to be procured from anything up to half-a-mile away from the scene of operations.

Utilisation

Having reached agreement on plant, lay-out and process, the plant is then installed and personnel nominated to recommend the detailed set-up which will give most efficient use of plant, materials, services and manpower, with a bias towards the factor which is most expensive or least available.

This involves very close consideration of handling on and off the machine, of feeding and in some cases of the necessity for welding as well as the importance of adequate servicing and planning to reduce change-overs. In fact, one of the most serious shortcomings of the comparatively modern plant in one of the larger Witton shops was that feeding arrangements were poor and slow, resulting in an "absolute" machine efficiency of only 33% approximately, whereas machine efficiency should never be less than 50% and, at the finishing end of the process, ought to be 75% or even 80%—higher figures are obtained on slower plant and/or with very heavy welded coil weights.

Shifts

Before we finish our consideration of plant efficiency, I must warn you that there is one further factor which the steel and chemical people, like their American counterparts, have learnt to employ. This factor is the *employment of the good plant* and process at least on double-shift, wherever possible on three shifts and in special cases throughout the 168 hours, *and the closing down of the bad* and inefficient plant and the avoidance of additional capital outlay.

Concentration

Concentration of work on the "good" plant is a factor which I would stress, particularly so far as the metal producing industry is concerned. Unfortunately, we tend to give equal employment to the old and the new plant, the bad and the good, in an endeavour to avoid differentiation in the treatment of the people employed in them. To me this is another instance of killing by kindness since it is quite apparent that if one plant will produce 60 lbs. per man-hour and another only 15, to employ these plants equally is indefensible from any long term consideration; yet it happens. Worse still, because the 15 lbs. per man hour represents a higher level of physical efficiency, the poorer plant is often credited with a higher unit hour than the better one and all sorts of fallacious conclusions may be drawn therefrom. Obviously the ultimate objective is concentration on the good plant, and the attainment in it of the highest man, machine and material efficiency which is possible in combination.

I would like to see shift conditions improved sufficiently to persuade intelligent workers to go into more productive plants although they may have, at the beginning, conservative objections to shift employment. If we were not "fogged" by general shortages, rationing and controls, workers would be attracted also by the greater security of an efficient plant. In America, where selling prices agreements are illegal and profits not immoral, workers deliberately seek employment where profits are high—an index of their security.

Labour

At this stage, too, there must be very careful measurement of the amount of useful employment for the operators and consideration of ways and means of minimising what is called ineffective time. Investigation must also be extended to the "fetchers" and "carriers", whom we call "servicers", and the maintenance personnel, so as to ensure that there is a proper balance of labour between what is required to operate the machine, to feed it, to clear it and to maintain it. All these investigations are, in fact, the proper field of Work Study.

Uses of Information

The detailed analysis of fact which Work Study builds up is then capable of use in planning, scheduling and costing, pricing and forecasting—our progressive American friends use Work Study for all these jobs.

At present most of our planning and scheduling is done on the basis of past performance and if we reproduce the previous best we feel we have done very well, although that best might only be three-quarters or even half of the potential. Similarly, our costing and forecasting have until very recently been comparisons with previous periods, without any allowances for abnormal circumstances involved in them or in the current period, whereas we are now beginning, *via* standard costing, to compare our current costs with what they ought to have been if we had used consistently the best plant and process and given proper attention to material yield and machine efficiency.

Suggestions—Use and Misuse

The Americans popularise the use of Work Study in yet one other direction, i.e. they encourage the workers themselves to use this sort of approach in putting forward their suggestions. I expect that you will all say that we have suggestion schemes. So we have, but what do they produce? Ideas certainly, but often they are confined to consideration of safety, welfare and amenities. Once workers understand that an improvement in the standard of the job can only come from concentrated study of the job, and improvement of its productivity, then perhaps our suggestions will be worth paying for.

Many workers have got into the habit of using their ideas to improve the earning power of their own job up to what they regard as a safe limit, without realising how short-sighted this is. That way they might get an extra 10/- per week. If they put their cards on the table and really used their ideas and the suggestion scheme properly for their ventilation, they would get an attractive lump sum, a chance of

promotion and the certain knowledge that they have done their bit in reducing the cost of living, to-day's most serious problem.

Solution

It is of the utmost importance that all job write-ups cover all the aspects of the job; e.g., from where does the product come, and where does it go; is the working area congested; what are the handling facilities; what is the unit weight before and after; precisely what is the process, and in some cases even, what is the previous process because a change in this may appreciably affect the job now being considered. Far too many of our current troubles arise from insufficient description; and for the future this recurring difficulty must be avoided. We must be able, for the future, to "pin-point" the change.

This work calls for Joint Consultation of a deeper character than is general to-day. It calls for appreciation of the true partnership of management and workers in industry. It requires from management a just, but friendly attitude, willingness to put their cards on the table, tell the workers how things are going in their shop and their factory, and from the management and workers equally, abandonment of all restrictive practices: including the worst and most prevalent—'that's how we've always done it'.

Incentives

Having cleared the ground in this way, Work Study will then, and not till then, recommend methods of payment which are loosely called incentives, which can be individual or group. Unfortunately, since this is the only part that shows above the surface it is possible that to many Work Study has appeared merely a means of fixing prices and bonuses. This is very far from being the case since the greatest savings can come, and frequently do come, from recommendations on improved handling, obviation of machine lost time, longer operation of fewer machines, shortening of process routes, standardisation and specialisation.

Material and Stores Economy

Now we must consider material efficiency, stores economy and, especially since the war, utilisation of power and fuel. In modern metal rolling mills material efficiency is extremely important. For instance, the process may have been standardised on a 25" wide casting, and, unless it is fully appreciated by all concerned that 24" of the 25" ought to be sold, much edge scrap will occur and become accepted as unavoidable.

To-day, stores such as oil, rag, paper and especially protective clothing, are exceedingly expensive and management must know what quantities are necessary per day, or week, to do the job, properly. Arbitrary rationing might increase scrap or cause accidents.

These matters are usually considered to be the province of the planning and purchasing departments, but they also must get their basic information from the same source as that on plant efficiency, i.e., from actual study of the job and its requirements.

Power and Fuel

Power utilisation is a most important factor since modern power houses, like electric casting, cannot be shut down for short periods. Balanced employment of power would substantially reduce generating costs and overcome the winter problem. Coal, whether used by the power stations or ourselves, is still our most valuable national asset and should, therefore, not be wasted. Almost all our fuel oil is imported and paid for in dollars. Similarly, we must use it as economically as possible.

Other Uses

When any two departments (or works) engaged on similar products have been evaluated, both in regard to their direct and their indirect operations, all the details can be aggregated into a departmental pattern from which can be discerned what is the relative efficiency of the one department compared with the other.

It is also possible to discover which of two processes is the more efficient in the overall sense, i.e., when the total cost of wages, power, supervision and services have all been accounted for. From both shop and process study it is possible to ascertain the strength or weakness within any one plant or process, i.e., a good shop may have a poor unit and, conversely, a bad shop may have a good one. It may even be necessary to consider how we can overcome what we all know as a "bottleneck" in production, e.g., there may be more rolling than annealing capacity in one plant, while the reverse position may exist in a plant nearby. These overall considerations of departments and processes are termed "Process and Methods Study" and, in fact, like the egg, this part of study work is both the beginning and the end, i.e., the conclusions we draw from our detailed investigations of an existing plant provide us with the framework for formulating a scheme for new plant and so the process goes on.

Incentives

So far I have mentioned incentives only in passing and this was quite deliberate. I am, however, quite certain that it is only on such methodical studies as have been outlined that we can build up rational incentive payments: and only if we have detailed records of the conditions when certain rates were applied can we justify the steps to alter payments when those conditions have changed. I am aware that many such changes are bound to be unpopular with the individual, despite Trade Union agreement authorising change of payment when change of conditions can be demonstrated.

Although I must repeat what I said at the beginning, that industry does not exist to find a lot of people comfortable jobs, nevertheless its first responsibility is to pay all on its payroll a minimum living wage, with additions for skill and responsibility and, on top of this, for a proper increase of effort or

efficiency, but not for improvements in plant or process productivity, the operator should receive a bonus of around 33⅓%. (He is not entitled, let me stress it, to all he can make by "sharp practice").

Then I must make clear that what are called profits must be devoted, first to the repayment of the cost of providing, installing and planning the new plant—in our Company it has been calculated that the proper equipping of each employee costs the Company a capital outlay of £6,000; secondly, to a reduction of selling price—to ensure at least our former share of the market and, preferably, an increasing share, as well as doing our part in the direction of a reduced cost of living; thirdly, to building up a reserve for still better plant, buildings and amenities. At present the Government, *via* taxation, takes the first "cut" at the cake.

Summary

Summarising what I have said so far, I am in fact recommending that Work Study, which is not a panacea but merely a measuring "tool", should be used by management and technicians to attack the following potential weaknesses:

1. The type of plant and process employed.
2. Its lay-out so as to minimise walking and crane time.
3. Its utilisation including:
   (a) Its servicing and maintenance to eliminate so far as practicable lost time of both man and machine.
   (b) Handling arrangements on the machine, and to and from the machine.
   (c) Changeovers—both in frequency and duration.
   (d) To decide how many hours in the week the machine ought to be employed—in simple terms, if overtime payments cost more than depreciation and fixed overheads, the answer is generally "no" so far as shifts are concerned, but if the opposite is the case, shifts should be employed to reduce the effects of depreciation, etc., and improve power costs.
4. Overall labour utilisation in order to balance up time requirements of the individual contributions so as to increase production per man-hour or machine-hour and to ensure adequate servicing and maintenance balance.
5. Material yield and stores.
6. Power and fuel usage.
7. Having acquired considerable and accurate information as to what can be done, to plan the work so that it is done.
8. To compare what the job or product has cost with its "budgeted" cost.
9. To influence fair apportionments of savings between customer, employee, investor and reserves.

All the above factors obviously bear on the activity of the operative and, in general, he will understand them, but there are others which need consideration including:

10. *Sales Policy*
    It is of the utmost importance where plant and processes have been designed for bulk (mass) production that selling policy should recognise this fact. It is not only very much more disturbing to make small lots in a mass production plant, but it is actually very much more expensive and if "specials" have to be produced, some part of a big plant, or a separate small plant, should be retained for their manufacture.
11. *Stocks and Records*
    The records which are provided should enable very much more accurate information on costs and stocks to be available, but again the system and the location of the personnel should be designed to avoid any unnecessary duplication and to obviate walking or postal time. Clerical duties should be examined with a view to their integration and simplification.
12. Last, but not least, management must examine themselves in order to ascertain how much of their working day is productive and how much is spent on routine matters which could be done as well, and probably better, by an ordinary clerk.

Perhaps you will now realise that the field of Work Study is very wide—in fact, there are no limits, since it is merely an organised commonsense investigation of the efficiency of man, machine and material, and can be carried out in any plant, old or new, large or small. It is this broad employment of Work Study which I think will give us an answer to our productivity problem.

RESEARCH PUBLICATIONS

A number of copies of the following Research publications are still available to members, at the prices stated:

Report on Surface Finish, by Dr. G. Schlesinger	15/6
Machine Tool Research and Management	10/6
Practical Drilling Tests	21/-

These publications may be obtained from the Production Engineering Research Association, "Staveley Lodge", Melton Mowbray, Leics.

THE PRACTICAL APPLICATION OF STATISTICS TO PRODUCTION ENGINEERING

by RONALD E. FRY, BSc., A.I.S., F.S.S.*

Presented to the London Graduate Section of the Institution, 26th November, 1953.

TO undertake to give an introduction to statistics in the limits of a single Paper is rather ambitious. Statistics is a subject which is already of considerable magnitude and complexity. Moreover it is still growing, at a pace which is the despair of industrial statisticians who have little time to give to detailed study of the current literature. For these reasons, no attempt will be made to supply any detailed methods of analysing technical data (except for methods of the simplest kind). Instead, it is hoped to explain some of the basic ideas underlying the majority of statistical methods, however complicated the latter may be. These ideas are essentially the scientific statement of commonsense, almost intuitive notions about the sort of highly variable data that we are actually required to deal with in our day-to-day engineering problems, as opposed to the beautifully behaved figures that are encountered in books on mathematics and engineering theory.

The Meaning of Error

A hypothetical situation will now be described which will serve to illustrate various points subsequently to be discussed.

Consider a production line with an output of Y items per day. Suppose that X is the most important factor influencing this production figure. For example, X might be some quality of the raw material fed in at the beginning of the production line. Now a mathematical formula relating the two quantities would simply express Y as a function of X,

thus, $Y = f(X)$

This formula implies that, given a fixed value of X, there would always correspond exactly the same value of Y. But does this happen in actual fact? It most certainly does not. Any production engineer is aware that to fix the level of a single factor in a complex manufacturing process is unlikely to ensure a uniform production rate. What else can be done to reduce variation in the rate of production? Obviously further factors can be picked out which are also known to be important. Thus Z might be one other such factor, say, machine setting. Once again, a mathematical formula could be calculated, this time relating output (Y) to X and Z,

thus, $Y = f(X, Z)$

and once again this mathematical model can be compared with the facts. If we fix X and Z at chosen levels, the formula indicates that an unvarying value of Y will result. This, of course, is no more strictly true than before. In practice, there will still be variation in the final output even though it may not be as large as before.

Now this process can be continued, but there is a limit to the number of factors which we know affect the output. Normally, these known factors account for most of the possible variation and this makes it possible to control the product within permissible limits. But the important point that it is desired to make, is this; there is always a multitude of smaller factors which we cannot define and which we cannot control. These factors might be almost anything, e.g. the temperature on the shop-floor, what the machinist had for breakfast, etc, etc. The remaining fluctuation in the output due to these small factors is called by statisticians the "error" of the process. The word "error" must not be interpreted in its everyday sense of "incorrectness". It is another example of science borrowing an ordinary word and giving it another and strictly defined meaning. Error in our context means the inherent uncontrolled variation of the process. Statistics differs from the rest of mathematics in that, instead of ignoring the existence of this random variation, it takes it into account and studies its behaviour. The idea of "error" is fundamental in statistical theory.

Frequency Distributions

How can we describe and study statistical error, or indeed, any kind of random variation? This is done by expressing the variation in the form of a *frequency distribution*, as follows:

Referring back to the example in the last paragraph, suppose that every factor known to affect the output Y, has been fixed, and that it is desired to study the remaining variation. Let us keep records of

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production per day over a long period during which these conditions prevail. The figures obtained can be classified as follows:

Divide the range of production rates into intervals spaced, say, 100 items per day apart, and count the number of production rates falling into each interval. These numbers are called the "frequencies" for each interval. The first two columns of TABLE I show the result of this classification which is called a frequency distribution.

TABLE I

Production (Items per day)	Frequency	Percentage Frequency	Cumulative Percentage Frequency
400 – 499	20	6.6	6.6
500 – 599	43	14.3	20.9
600 – 699	51	17.0	37.9
700 – 799	79	26.3	64.2
800 – 899	62	20.7	84.9
900 – 999	31	10.4	95.3
1000 – 1099	14	4.7	100.0
TOTAL	300	100.0	

The first step in studying the distribution is to represent it graphically in the form of a histogram as shown in Figure 1. Note the shape of the distribution in this instance. It is a very common shape in statistical frequency distributions, namely, single-humped and symmetrical. It has been shown by both theory and practical experience that, in the case of a variable which is subject to a large number of simultaneous and randomly occuring causes of variation, it is generally distributed with a similar single-humped, symmetrical shape known as the "normal distribution" which is illustrated in Figure 2.

Consequently, it is common in practical statistics to use this distribution as a mathematical model for actual frequency distributions which fairly closely resemble it. There is a simple practical method for testing the "normality" of a distribution. First, form the cumulative percentage frequencies of the distribution as shown in the final two columns of TABLE 1. Now there is a special kind of graph paper sold by several well-known manufacturers of scientific stationery, which is known as "probability paper". The vertical axis corresponds to the cumulative percentage frequency and the horizontal axis corresponds to the actual variation being considered (in this case, Y, the output per day). This graph paper, has the property that, when the cumulative percentage frequencies of a distribution are plotted on it, and if the distribution is normal, the points will lie in a straight line. Thus in Figure 3, the cumulative percentage frequencies from TABLE 1 are shown plotted in this manner. The closeness to normality of this distribution is thus clearly demonstrated.

Probability paper can be an extremely useful practical tool for the study of distributions, and after some experience, the application of a little thought

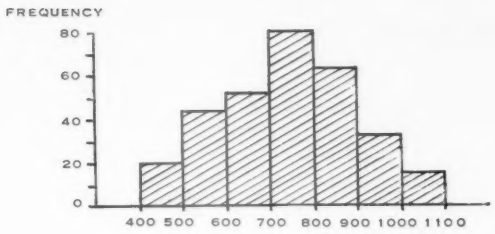


Fig. 1. Production in items per day

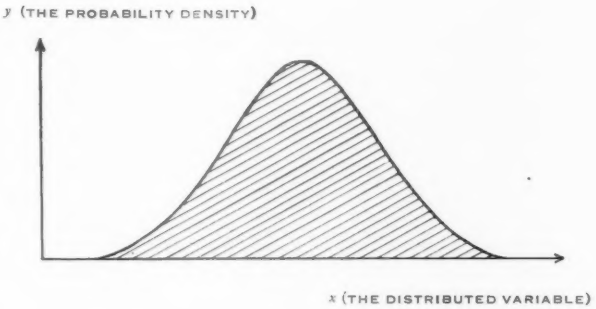
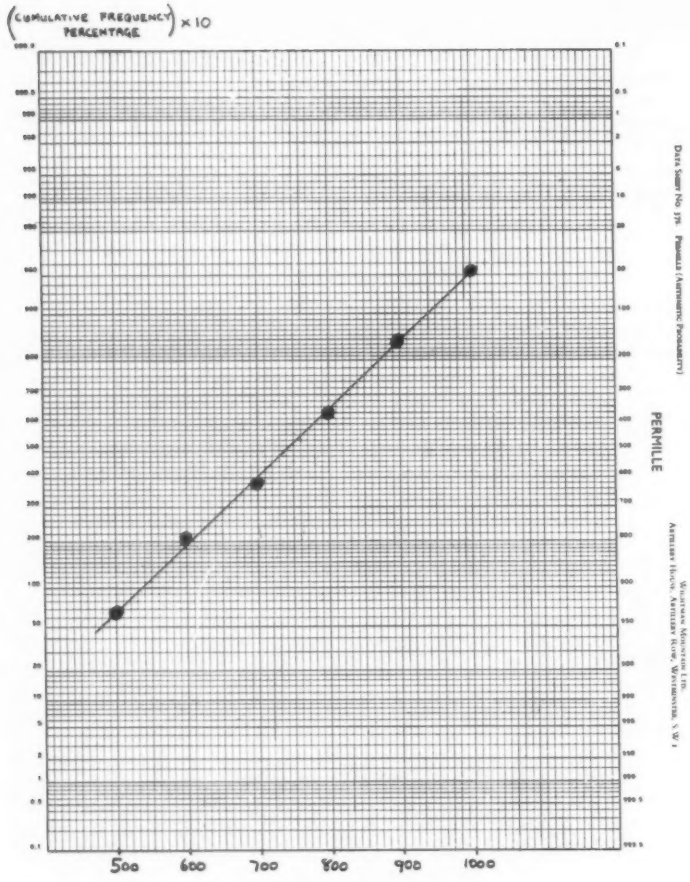


Fig. 2. The curve of the normal distribution

and ingenuity will reveal a multitude of other ways in which it can be used to solve problems.

One interesting example in the author's experience was when a production engineer wished to investigate changes in the distribution of bonus rates. Unfortunately, the only data to which he could be given access were individual bonus rates over 100%, and the total number of all bonuses. No details of individual bonus rates less than 100% were available. However, it was known that bonus rates were approximately normally distributed, and by working out cumulative percentage frequencies (starting this time from the *upper* end of the bonus scale) it was possible to obtain a part of that straight line on probability paper, which represented the whole distribution. Simple extrapolation of this straight line immediately supplied details of the rest of the distribution, and by studying changes in slope and position of the line, the engineer was able to keep track of changes in the distribution of bonus rates with a minimum of effort and calculation.

This digression on the normal distribution has been made because it is clearly of little use to plot frequency distributions unless something is known of how they may be expected to behave. On the other hand, it is not to be expected that all or even most distributions are normal. Non-symmetrical distributions are called "skew" distributions and are generally one of two types. Either they are non-symmetrical single-humped types as shown in Figure 4 or they are reverse 'J' shaped as shown in Figure 5. This latter type is very common in scrap distribution, e.g. the distribution of the number of rejects in samples of say, 100 items from production. One



Production in Items per Day
Fig. 3.

feature of such a distribution is the existence of a lower limit to the variable, and such a lower (or upper) limit is often accompanied by skewness. This is only one cause, however, and it is impossible here to go into detail about the meaning and causes of skewness. In any case, it will usually be found that it can be given a fairly obvious commonsense explanation on technical grounds without the need for any statistical theory. For example, in the scrap distribution just considered, it would be naturally expected that in a well-controlled process, samples containing very little scrap would be the most common, the frequency decreasing as the number of scrap items in the sample increased.

Practical Uses For Frequency Distributions

Now that at least some idea has been given of what frequency distributions are and how they behave, it will be pertinent to give some examples of how they have been actually used to obtain useful and previously unsuspected information. The first story illustrates statistics as a means of detecting incorrect inspection methods.

This example occurred in a large firm manufacturing electrical wiring and cabling. One of the routine tests on the wire was to count the number of pinholes in the enamelling of a two foot sample of wire. This test was always carried out by the same operator, who worked in a secluded spot out of range of any direct supervision. One day it was decided to investigate this type of defect by analysing the results of this test that had been collected up to that date. As a first step, the results were plotted in a frequency distribution. One would naturally expect such a distribution to conform to one of the types already described. To the astonishment of the investigator, it turned out to be almost completely rectangular! After brooding over this strange result, the conclusion was reached that all was not as it should be. In consequence, a watch was kept upon the testing operator without his knowledge. It was soon discovered that on being given a batch of samples, he would make a show of beginning to test them, but as soon as he considered he was unobserved, he would merely write down a series of results selected at random from the range of possible results, and thereafter do no further work on the samples. Since he would, in the long run select each of the possible results an equal number of times, the fictitious figures had a rectangular distribution.

Another example is also concerned with detecting an incorrect testing procedure, but this time the mistakes were not deliberate. A statistician in an electrical engineering firm happened to be watching an operator doing a routine test on a manufactured component. The readings were taken off a dial gauge. It was suddenly noticed that in some cases the pointer on the gauge instead of only moving part of the way round the dial, completely circled the dial before coming to rest. It was also noticed that the operator did not seem to be aware of this, and merely read off the dial as if this had not happened. When it was pointed out by the statistician that this was so, the only response was a firm denial, the operator insisting that this never happened.

In order to establish the point, the statistician collected previous records of the test and plotted them in a frequency distribution which looked like Figure 6. It will be noticed that this distribution is cut short at the highest reading on the dial and is inflated at the lower end. Admittedly it is quite feasible that all readings should be less than this value, but if this were so, one would hardly expect the distribution to be of such a shape, that is, with values right up to this highest value being quite frequent, but suddenly stopping after this point. It

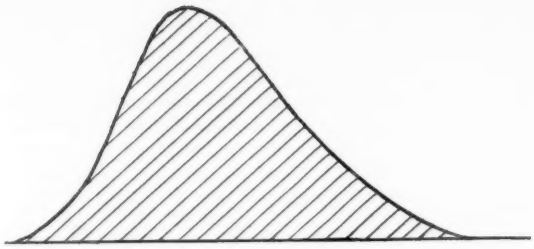


Fig. 4. Unimodal Skew Distribution

is clear that the statistician was right, and that rotations of the dial pointer through more than 360° were being mis-read.

Numerical Description of a Distribution

It is hoped that the reader has a reasonable idea of the sort of uses to which simple frequency distributions can be put. Some extensions of this idea will now be dealt with which are also fundamental to statistical methodology. Having obtained our frequency distribution, it is necessary, if our work is to be precise, to describe its properties numerically.

What are the important properties of a distribution? First, it is necessary to know whereabout on the scale of values the distribution is located. This is indicated by the "central" value. This "central" value is most often specified by the ordinary arithmetic means of the distribution. Other types of central value are the "mode", that is, the value with the highest frequency, and the "median" which is the value which exactly divides the total frequency into two equal halves. Which one is chosen as most typical of the central value of the distribution depends very much on circumstances. The arithmetic mean is the most important of the three because it has useful mathematical properties and is always exactly defined. On the other hand, the mode and the median are not so heavily influenced by extreme values as it the mean, and in certain cases may appear more "representative" of the location of the distribution. They are not, however, always exactly defined.

The other important property of a distribution is its "spread". The nature of a difference in spread is shown by considering (Figure 7) a tall narrow distribution compared with a short wide distribution, both on the same scale of units. The one represents a consistent quantity while the other represents a more variable quantity. Thus a measure of spread is a measure of variation and its importance will be realised when it is stressed that statistics is essentially the study of random variation. Now the most important measure of this "spread" or variation is called the "variance". It is defined as the mean of the sum of the squares of the deviations of the observations from their arithmetic mean. Thus, if the total number of results x, is N, then:

$$\frac{1}{N}\sum (x - \bar{x})^2 = \text{Variance} \qquad (\bar{x} = \text{arithmetic mean of the x's})$$

The square root of the variance is another well

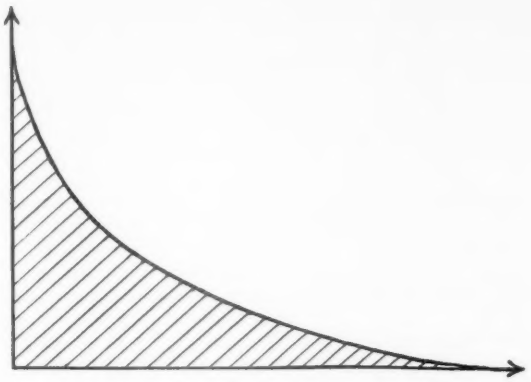


Fig. 5. Reverse J-shaped Skew Distribution

known measure of variation which is known as the "standard deviation".

$$\text{Thus, Standard Deviation} = \sqrt{\frac{1}{N}\sum (\bar{x} - x)^2}.$$

This often has more appeal to the practical man because it is essentially a "linear" measure of variation, i.e. it can be expressed in the same units as the quantity whose variation it measures. Thus, if we have a distribution of, say, pressures measured in pounds per square inch, then the standard deviation of their distribution will also be expressed in pounds per square inch.

The Analysis of Variance

The importance of the variance lies mainly in its unique and important mathematical properties. The most important of these is what is called the "additivity of variance". This is illustrated by the following example. Suppose there are three parallel production lines in a factory, each quite independent of the others. Then we can calculate the variance of the output per day separately for each line. If we add together the outputs of the three lines and obtain a total figure for the output, then the variance of this total output will be equal to the sum of the three separate variances.

This discussion of the variance as a measure of variability and its additive property leads now to what is probably the most important and powerful

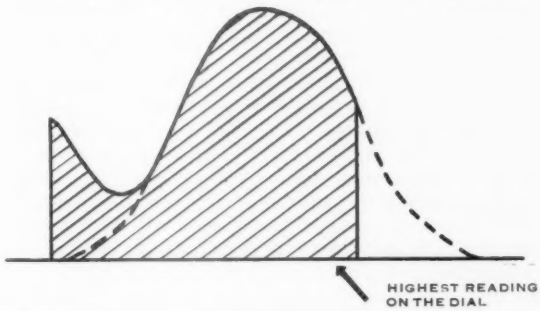


Fig. 6. Truncated Distribution Arising from Incorrect Dial Readings

Fig. 7. Graphical Comparison of Distributions with Low and High Variances

tool used in modern industrial statistics, i.e. the Analysis of Variance and its associated subject of Experimental Design. Let us revert to the example given at the beginning, i.e. a production line with an output of Y items per day which is influenced by certain known factors X and Z (and possibly others). This situation is typical of the majority of experimental situations in engineering and applied science. One investigates the effect upon a given variable, of varying certain factors which are believed to be important, the object being to estimate the relative importance of these factors and possibly to obtain some formula connecting them with the variable being studied. Now, if a variable such as the production line output Y is being affected by changes in various factors X, Z, etc. (which might be such things as raw material, machine settings, etc.) then if we calculate the variance of the output figure Y, it is reasonable to expect from the theorem on the additivity of variance that it could be split up into components due to each of the factors, i.e.

i.e. $v(Y) = v_1$ (due to X) + v_2 (due to Z) + etc.

It is a similar process that the Analysis of Variance is designed to carry out. Having performed such an analysis it is possible to see which of the factors are having the major effect on Y. This in itself is interesting and useful, but it does not comprise the whole story by any means.

Firstly, in what form must the data be, in order to carry out such an analysis? This is where the subject of Experimental Design comes into the picture. These designs specify the way in which it is necessary to collect the figures in order to be able to perform the Analysis of Variance. The subject has by now become very complex, but in the present context, the most important type of design is what is known as the simple factorial design. The principle of such designs is perfectly straightforward and they can be constructed as follows.

First decide on the variable which it is desired to investigate. Then decide on the factors in whose effect on this variable, you are interested. Decide on the number of levels of each factor that it is desired to experiment upon. Then the design merely consists of carrying out all possible combinations of factor levels. Thus, reverting to the original illustrative example, suppose it is decided to investigate the factors:

X = quality of raw material (Two levels X_1 & X_2)
Z = machine setting (Two levels Z_1 & Z_2)

Then there are four possible combinations of experimental conditions:

(X_1, Z_1)	(X_2, Z_1)
(X_1, Z_2)	(X_2, Z_2)

It will be noticed that the number of experiments required for two factors, each at two levels, is $4=(2\times2)$. If there had been three factors, each at two levels, then the number of experiments required would have been $8=(2\times2\times2)$. Of course, a factor can have more than two levels. Thus in a two factor experiment, if factor X had 3 levels, and factor Z had four levels, then the design would require $12=(3\times4)$ experiments which would be as follows:

(X_1, Z_1)	(X_2, Z_1)	(X_3, Z_1)
(X_1, Z_2)	(X_2, Z_2)	(X_3, Z_2)
(X_1, Z_3)	(X_2, Z_3)	(X_3, Z_3)
(X_1, Z_4)	(X_2, Z_4)	(X_3, Z_4)

It is necessary to use more than two levels in a factor if it is desired to investigate the existence of any curvature in the relationship between the dependent variable and the factor.

These methods of experimentation have certain powerful advantages. In the first place, all the factors are investigated simultaneously instead of one at a time. But the most striking advantage is this. Not only can the total variation of the results be analysed into components corresponding to each of the factors, but the Analysis of Variance will also isolate components due to what are called the "interactions" of the factors. The effect of a factor on the dependent variable will very often depend on the level of another factor. If this is so, there is said to be an interaction between the two factors. Thus, suppose that the following output figures (Y) were obtained in our simple 2-factor experiment. It will

	X_1	X_2
Z_1	5200	6500
Z_2	6300	4800

be noticed that when factor Z is at the lower level Z_1, then the effect of changing from X_1 to X_2 is

to *increase* production from 5200 per day to 6500 per day. But when Z is at its upper level Z_2, then the effect of changing from X_1 to X_2 is to *decrease* production from 6300 to 4800 per day. Thus the effect of X is very much dependent on the level of Z. An interaction of two factors need not involve an actual reversal of an effect, but may merely consist of the reduction of the magnitude of an effect. Interactions are extremely common in engineering and it is clearly of the first importance to be aware of their existence. Factorial experimental designs are the easiest and most economical way yet devised for detecting them.

An example of an interaction that actually occurred is as follows. The process being studied was the casting of copper-lead bearing metal as a lining into steel shells. The variable measured was the shrinkage of the metal on cooling. Two of the factors were the thickness of the lining and the amount of phosphorus added to the melt as a deoxidant. The process was investigated with the aid of a factorial experiment and a strong interaction was detected between these two factors. On looking into this, the interpretation was found to be that whereas when thick linings were being cast, it was better to use a high amount of phosphorus, when thin linings were being cast, better results were obtained with a low amount of phosphorus. This was previously unsuspected and together with other items of similar information obtained from the same experiment, was applied in order to reduce the percentage of scrap.

Economy in Experimentation

This particular casting experiment was an interesting example of a type of factorial experiment known as a fractionally replicated design. The main point of these designs is as follows. If it is wished to investigate a *large* number of factors simultaneously, then an ordinary factorial design will begin to grow very large as the number of factors increases. For example, the experiment concerned with the casting of copper-lead contained fourteen factors each at two levels. Now to carry out the full design would have involved $2^{14}=16{,}384$ experiments. It was felt that the Managing Director, not to mention the Foundry, might feel certain qualms about carrying out a piece of research of this size. In such cases, it is possible to use fractional replicate designs in which only a fraction of the total experiment is carried out and yet all the important information on the main effects of the factors and the more important interactions are still conserved. These fractions are always powers of one-half, i.e. they are a half, a quarter, an eighth, a sixteenth, etc., of the total experiment. How small a fraction can be used without losing valuable information depends on the number of factors involved. The greater the number of factors, the smaller the fraction that can be used. The copper-lead experiment involved 14 factors and it was possible to use $\frac{1}{2^8}$th of the total experiment. Since $16{,}384=(128)^2$ this meant that the actual number of experiments carried out was 128, which is a far cry from 16,384. This was probably one of the most ambitious fractional replicate designs ever attempted in industrial research in this country, and is rather larger than most. Each of the 128 castings was measured for not one, but several variables and a separate analysis was required for each variable. Complex systems of interactions were discovered in each case and in all, the analysis and interpretation of the results took several months. The point is, that by the old methods of experimentation, to obtain only a fraction of all this subtle and detailed information might have taken a couple of years and would have involved considerably more experimental work at much greater cost. Thus it can be seen that industrial applications of modern statistical methods can make process control much more efficient than ever before at a considerably lower cost.

It is hoped that enough has been said about the Analysis of Variance and Experimental Design to arouse the interest of the reader sufficiently for him to look into the subject in more detail. The account of the subject given here has necessarily been considerably over-simplified and it has not been possible even to give a brief account of all the details of planning, carrying out analysing such designs. An excellent handbook for someone who wants some practical instructions on these points is the Stationery Office publication, " Industrial Experimentation ", by K. Brownlee (H.M.S.O. 1949).

Analysing Figures from the Files

One could describe the Analysis of Variance as the " analysis of *controlled* data ". That is to say, it is decided beforehand (by means of an experimental design) under what conditions our data is to be obtained, and one then goes ahead to obtain it. Now many engineers are probably more accustomed to thinking of statistics as applied to what might be called " *uncontrolled data* " by which is meant the sort of data which just " happens " e.g. routine production records. What can be done with this sort of data, where factors vary haphazardly and not according to a predetermined system? To these kind of figures can be applied what are known as " correlation techniques ".

Let us return again to our example of the output of a production line. Suppose production records are available over a period of time, of the output Y, and the corresponding values X of a particular quality of the raw material. It is desired to determine whether X has any influence on Y. The first thing to do is to plot X against Y in what is called a " scatter diagram ". (Figure 8). This might seem obvious, but it is surprising how often the person concerned does not realise this. Very often, in attempts to establish a relationship between two random variables, people will construct some incredibly elaborate diagrams which are chiefly successful in completely obscuring any information contained in the figures. Making this simple diagram is all that is necessary. Having constructed the diagram, it will often be immediately apparent that there is a definite relationship and it may not be desired to go further. But quite often an elliptical cloud of dots will be obtained which might or might not indicate a correlation between X and Y. This is where statistics comes into its own. It is possible to calculate from

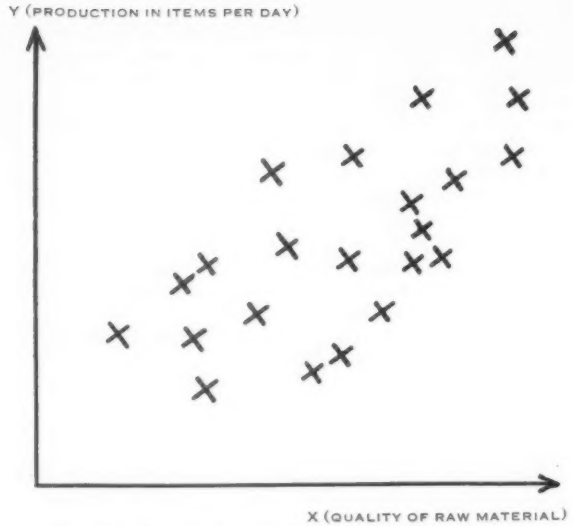


Fig. 8. Hypothetical Example of a Scatter Diagram

the data what is called the "correlation coefficient". This always lies between –1 and +1 and the greater its numerical value (i.e. the nearer it lies to either –1 or to +1,) the greater is the degree of correlation. If, on the other hand, it is close to zero, i.e. its numerical value is small, then a low degree of correlation is indicated. It is possible to test quite simply, by means of tables specially calculated for the purpose, whether the value of the correlation coefficient which is obtained actually proves the existence of any correlation between Y and X. Instructions for the necessary calculation and testing of the correlation coefficient are given in Brownlee's book referred to earlier.

It is easy to see that this simple but useful technique is of extremely wide application. Just one practical example will be given. Many boiler fuels have an ash content which is chiefly dependent on the percentage of "fines", i.e. the percentage of coal dust below $\frac{1}{8}$" in size. At one time, when working in a power station, one of the Author's duties was to carry out such correlations between ash content and percentage "fines" for various types of boiler fuel, in order to establish that the reason for increasing ash content was failure to wash the fuel properly at the pit-head. Such correlation analysis gave a firm basis on which to register complaints about quality in the appropriate quarters. This is what one might call the "tactical" use of statistics. A correct statistical analysis can often give you a firm platform from which to argue your case. If your opponent is statistically educated he will have to admit the force of your argument and if he is not, he will often be rather impressed and will probably hesitate to argue about something of which he has no knowledge!

When you have established the correlation, you will often want to draw some sort of curve connecting the two variables, so that given a value of one variable you could predict the value of the other. Now it is necessary to think clearly on this issue. Really there is no such thing as a "true" line or curve connecting the two, in most cases. The scatter diagram itself shows that given a fixed value of X one can obtain any one of a whole range of values of Y. Therefore, if one uses a line or equation connecting Y and X, it must be such that the values of Y predicted by the line are the "best" estimates that one can get under the circumstances. It is necessary, of course, strictly to define the word "*best*". It is defined here as being the value of Y such that the variance of all the deviations of the possible values from this predicted value, is at a minimum. In simpler language, the line is calculated so that the variation of the actual values around it is a minimum. It is for this reason that if one is using the line to predict the "most probable" Y from a given X, a different line is used from when it is required to predict X from Y. In the case of an elliptically shaped cloud of dots such as the scatter diagram in Figure 8, it is customary to fit a straight line with an equation of the form,

$$Y = ax + b$$

If, however, the relationship clearly involves some curvature, it is possible to fit equations of higher order, e.g.

$$Y = ax^2 + bx + c.$$

These curves and lines are called "regression curves" and their equations are called "regression equations". It is also possible to calculate limits on either side of these curves within which it can be predicted that 95% (say) of all possible values will lie. These are called "confidence limits". These should always be given because they enable you to state precisely how reliable your predicted value is. These correlation and regression techniques are simple to understand and use and, like a good many simple things, are very useful and well worth mastering. The details of computation of the correlation coefficient and regression equations are given in Brownlee or any simple text-book on statistics.

So far only correlation between two variables has been mentioned, but of course, cases arise where some quantity is related not to one, but to several independent variables. The ideas mentioned can be extended with the same underlying principles, to the case of several variables. In this case, one calculates "multiple correlation co-efficients" and "multiple regression equations", e.g.

$$Y = ax_1 + bx_2 + cx_3 + d$$

where Y is dependent on the variables x_1, x_2 and x_3. The same sort of ideas are involved but interpretation and computation of these analyses are more difficult and lengthy, and it is advisable to carry them out with the advice of a statistician. The arithmetic in any case, owing to its length and the almost inevitable occurrence of mistakes in manual calculations, necessitates the use of a calculating machine.

Conclusion

One could go on indefinitely describing the various techniques which are in day-to-day use in industrial statistics, but an attempt has been made to pick out a few which it was thought might arouse the interest of practising engineers and which could be explained without delving too deeply into theory. It has been necessary to leave out much that is important in this sort of work, and there is some overstatement in the claim of the title that this discussion has been an introduction to applications of statistics. In particular, some readers will notice that no attempt has been made to discuss the subject of quality control charts. This was because it was felt that if a production engineer has any acquaintance with statistics at all, it is most likely to be with control charts. There are many publications dealing with this subject from the engineer's view point and there was no wish to duplicate them. The aim has been rather to arouse the interest of engineers in the wider field of statistical methodology, and if possible, persuade them to look into the subject for themselves. The Author's belief is that the best industrial statisticians are always the competent amateurs, whose main training and occupation is in the disciplines of engineering and applied science, and to whom statistics is an invaluable tool in the planning and evaluation of their work.

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A short list is given of books which might be useful to those wishing to acquire some knowledge of the practical applications of statistics:

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COCHRAN, W. G. & COX, G. M. (1950), *"Experimental Designs", New York: John Wiley & Sons.*

DAVIES, O. L. (ed.) (1949), *"Statistical Methods in Research & Production" 2nd Edition, Edinburgh: Oliver & Boyd.*

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TIPPETT, L. H. C. (1952), *"Technological Applications of Statistics", London: Williams & Norgate.*

FUTURE INSTITUTION ACTIVITIES

Institution Annual Dinner, 1954, at the Dorchester Hotel, London, on Friday, 8th October, when the principal guest will be Lt.-Gen. Sir Ronald Weeks, K.C.B., C.B.E., D.S.O., M.C., T.D.

One-Day Conference on Materials Handling, organised by the Institution's Materials Handling Sub-Committee, will be held on 23rd October, in Birmingham. Details and application form appear in this month's Supplement.

Third Aircraft Production Conference, organised by the Southern Section of the Institution, will be held at the University of Southampton on 14th and 15th January, 1955. The theme of the Conference is to be: "Production Problems of Integral Construction Contrasted with Traditional Methods".

Social Functions. Members are asked to make a note of the following social events arranged by Sections:

Sheffield Section Annual Dinner, 11th October.

Western Section Dinner Dance, 14th October.

Coventry Section Dinner Dance, 15th October.

Lincoln Section Dinner Dance, 21st October.

Wolverhampton Graduate Section Dance, 22nd October.

Leicester Section Dinner, 25th November.

NEW BUILDING FUND APPEAL

Since the publication of the last list, donations have been received from the following subscribers. (The list was compiled for press on 14th September, 1954.)

B. T. Aston, Grad.I.Prod.E.

H. C. Blackford, M.I.Prod.E.
E. A. Boyes, Grad.I.Prod.E.
W. G. Brodie, A.M.I.Prod.E.
D. R. Brookes, Grad.I.Prod.E.

W. Calderbank, Grad.I.Prod.E.
S. Chakrabarti, Grad.I.Prod.E.
Churchill Redman, Ltd.
J. A. Cleal, Grad.I.Prod.E.
G. G. Coppola, A.M.I.Prod.E.

S. E. Davies, A.M.I.Prod.E.
A. S. Dick, M.I.Prod.E.

H. A. J. Edlin, A.M.I.Prod.E.

J. W. G. Ford, M.I.Prod.E.

W. A. Glen, M.I.Prod.E.
D. E. Greene, A.M.I.Prod.E.
W. P. Gill, M.I.Prod.E.

E. Hampshire, A.M.I.Prod.E.
J. D. Heys, A.M.I.Prod.E.
A. Hill, A.M.I.Prod.E.
B. G. Hill, Grad.I.Prod.E.
P. Holmes, M.I.Prod.E.
J. L. Hughes, Grad.I.Prod.E.

W. L. Jackson, A.M.I.Prod.E.
W. G. A. Jenkins, A.M.I.Prod.E.

L. W. J. Lait, A.M.I.Prod.E.

T. Macinerney, A.M.I.Prod.E.
H. J. Manners, Grad.I.Prod.E.
T. L. Morton, M.I.Prod.E.

H. Nicholson, A.M.I.Prod.E.
S. Nuttall, A.M.I.Prod.E.

H. W. Rainbird, A.M.I.Prod.E.
R. Redpath, Stud.I.Prod.E.
J. P. Rochford, Grad.I.Prod.E.
D. G. Rose, Stud.I.Prod.E.

R. A. Shrubsole, Grad.I.Prod.E.

M. E. Taylor, A.M.I.Prod.E.

A. Wakeman, M.I.Prod.E.
W. H. C. Webster, A.M.I.Prod.E.
J. F. Westaway, A.M.I.Prod.E.
D. H. Wheatcroft, Stud.I.Prod.E.
G. H. Whiteley, A.M.I.Prod.E.
J. Wright, A.M.I.Prod.E.

EXECUTIVE COURSES

The Institute for Engineering Production has arranged a series of short practical residential courses for production executives and senior specialists, which are being held from September to December, 1954.

The September course dealt with the application of work study, and the remaining courses will cover the following subjects:

October 4th - 15th

"Work Study—with special reference to Fuel and Power Utilisation and Economy".

November 1st - 12th

"The Application of Work Study in Hot Dip Galvanising".

November 15th - 26th

"Production Planning and Control".

December 6th - 17th

"The Use of Operational Research in Increasing Productivity".

The inclusive charge for the normal two weeks' residential course, covering text-books, course papers and all residential charges and meals, is £40 per member. Where members are unable to attend on a residential basis, the inclusive charge is £30.

Applications should be sent as soon as possible to The Senior Course Secretary, The Institute for Engineering Production, "Southfield", 16, Norfolk Road, Edgbaston, Birmingham, 15.

INDUSTRIAL INSTRUMENTATION AND AUTOMATIC PROCESS CONTROL

A series of evening lectures and demonstrations on industrial instrumentation and automatic process control has been arranged for the Winter Term by the Electrical Engineering Department of Battersea Polytechnic, covering temperature, pressure, level, flow, valve sizing, and an introduction to the mathematics of feed-back control.

Full particulars may be obtained from the Electrical Engineering Department, Battersea Polytechnic, Battersea Park Road, London, S.W.11.

JOURNAL BINDERS

Members are advised that binding cases for the Journal are available, and may be ordered from Head Office. The cases, which are strongly made and covered in dark red leather cloth, with "The Institution of Production Engineers Journal" in gilt on the spine, will each hold 12 copies of the Journal. The price per case is 10/-, post free.

Official Opening of New Headquarters

The new headquarters of the Institution at 10, Chesterfield Street, London, W.1., will be officially opened on Thursday, 28th October, 1954, by Sir Leonard Lord, K.B.E., Chairman and Managing Director of The British Motors Corporation.

It is obviously impracticable for every member of the Institution to be invited to attend on this occasion, but the President is most anxious that all Sections of the Institution should be represented. Invitations are being sent, therefore, to the Chairmen and Honorary Secretaries of each Section.

Final Report of the A.A.C.P.

With the recent publication of its last Report, "Industrial Engineering", the work of the Anglo-American Council on Productivity has now been concluded, but the far-reaching effects of its activities will continue to be felt in British and American industry for some considerable time.

It will be recalled that the Council was formed in 1948 on the initiative of Mr. Paul Hoffman, Marshall Aid Administrator, and the late Sir Stafford Cripps, then Chancellor of the Exchequer, with the primary object of finding means whereby the technical knowledge and experience that lies behind high productivity in the United States, could be applied for the benefit of British industry.

Since then, the Council has sponsored the visits of 67 teams to the U.S.A., and 72 Reports on specific industries and specialised technologies have been published, of which 690,000 copies have been sold. In all, 911 individuals toured the U.S.A., visiting 2,000 industrial establishments and travelling over 500,000 miles. In general, each team consisted of about 15 members, and the visits lasted for six weeks. They covered every important industry, from steel-founding to food canning; from heavy chemicals to rigid boxes and cartons; from diesel locomotives to cakes and biscuits. In addition, a number of teams studied specialist techniques such as materials handling, production control, and plant maintenance.

From the first, the Reports aroused widespread interest. They were closely studied abroad, and in the U.S.A. itself are widely used in industry, and in management and industrial education.

Every effort was made by team members to implement their recommendations, by talking to organisations in their own industries and to professional associations. In some technical colleges, the Reports are now widely used as textbooks of their subjects.

One of the most important discoveries which the teams made was that whilst the U.S.A. was not generally ahead of Great Britain in terms of new ideas and inventions, American industry was very much quicker in their application.

It was clear from the Reports that Great Britain has much to learn in this direction and this problem is now being vigorously tackled by the British Productivity Council, by the examination of productivity in specific industries, and by the publication of Reviews which give special consideration to the methods used to implement the recommendations of the A.A.C.P. Reports.

The Council was dissolved in 1952, but its success had firmly established the principle that a joint management and trade union approach to the task of raising productivity was not only desirable, but practical and effective.

In a letter published in "The Times" on 8th September last, the President of the Institution, Sir Walter Puckey, paid a personal tribute to those who had the vision to conceive the Anglo-American Council on Productivity, and to the courage and resourcefulness of all those engaged in its activities.

Speaking on behalf of the members of the Institution, the President stated that they placed a very high value on the work which the Council had begun, and said, in conclusion:

"The enthusiasm with which the American hosts received the Teams was in itself an inspiration, and there is ample evidence that they also benefited from this experience.

"The Reports contain a vast fund of information which has still to be assimilated and applied. In carrying forward this work, the British Productivity Council can, I am confident, be assured of the support of all sections of British Industry".

A review of the Report on "Industrial Engineering" has been prepared by Mr. B. H. Dyson, General Works Manager, Hoover, Ltd., and Chairman of the Institution's Research Committee. It appears on page 592 of this Journal.

Birmingham Section Tour

A party of twenty-eight members of the Birmingham Section recently concluded a successful and interesting tour of factories in Germany. The party received a very warm welcome at all the places they visited and all members taking part had a most enjoyable and interesting trip.

The tour was organised by Mr. Tom Houghton, who hopes to arrange a similar tour next year.

OBITUARY

Capt. F. W. SPENCER

The Institution records with deep regret the death of Captain Frank William Spencer, which took place in August, after an illness of some months.

Captain Spencer was a founder member of the Cornwall Section, of which he was Honorary Secretary for a number of years, before becoming Section President in 1952.

Born in Coventry, he was educated at King Henry VIII Grammar School and served his apprenticeship in engineering and draughtsmanship with Bretts Patent Lifter Co., Ltd., Coventry. He subsequently held positions at J. Hands & Co., Ltd., Birmingham; Nelsons, Ltd., Stockton; and Edgar Allen, Ltd., Sheffield.

In 1911, he went to America as engineer and demonstrator for the Sturtevant Mill Company, and in this capacity he travelled widely in the United States and Canada.

During the First World War he obtained a commission in the South Midland Royal Field Artillery and was seriously wounded at Ypres. After nearly a year's convalescence, he was for a short period engaged at a Royal Ordnance Factory before rejoining the active Forces and was serving with the 48th Division in Italy when he gained his Captaincy.

After the War he joined B.S.A., spending some time in Germany and America on their behalf. On his return from America he was appointed Production Manager at Holman Brothers, Ltd., Camborne, and later, Works Manager at Thos. Smith, Ltd., Saltley.

In addition to his enthusiastic and untiring work for the Institution, he was actively connected with the Association of Drop Forgers and Stampers and was also a member of the Institution of Mechanical Engineers.

Captain Spencer was essentially a man of outdoor interests, and his genial and friendly manner was an integral and outstanding part of a personality which endeared him to all with whom he came in contact. He will be sadly missed by his many friends and colleagues.

news of members

Mr. R. R. Kenderdine, Member, has been appointed an Executive Director of Crompton Parkinson Limited. He will assume full executive responsibility for the Company's Works both at home and overseas, with the exception of those at Guiseley and Doncaster. Mr. Kenderdine was appointed Production Engineer at the Chelmsford Works in 1949; subsequently he became Chief Production Engineer for the Company and he will continue his duties in that capacity for the time being, in addition to his new responsibilities.

Mr. Kenderdine

Mr. H. G. Ramsell, Member, has been appointed General Manager of both the British Lock and Hardware Division and the British Materials Handling Division of the Yale and Towne Manufacturing Company. The Company's British Lock and Hardware Division is at Willenhall and the British Materials Handling Division is at Wednesfield. At the time of Mr. Ramsell's appointment, he was General Works Manager of the British divisions. He first joined the Company in 1929.

Mr. H. Allinson, Associate Member, has taken up an appointment as Branch Manager of Messrs. Kilburn & Co. (Pakistan) Limited, Karachi.

Mr. A. T. Coote, Associate Member, is now the Assistant General Manager of John Dale Limited, New Southgate, and a Director of John Dale (Bury) Limited.

Mr. I. D. Corbett, Associate Member, has relinquished his postion as Assistant Grade B at Leigh Technical College to take up an appointment as Lecturer in the Mechanical Engineering Department at Aston Technical College, Birmingham.

Mr. M. B. Dhavale, Associate Member, has been appointed Sales Manager of Kirloskar Oil Engines Limited, Poona, where he was previously Works Manager.

Mr. J. Irwin, Associate Member, has relinquished his position as Production Manager with H. W. Carter & Co. Ltd., Coleford, and is now General Works Manager with Metalitho Limited, Cwmbran, Mon.

Mr. H. T. Jones, Member, Chairman of the South Wales and Monmouthshire Section, and Regional Chairman for Wales, has been paying a business visit to Melbourne. During his stay, Mr. Jones made a point of meeting as many members of the Melbourne Section as possible.

Mr. C. Lacey, Associate Member, formerly Production Engineer with Adamsons & Co. (Machines) Ltd., is now Works Manager with Dalton and Gallon Limited, Bradford.

Mr. F. Landmann, Associate Member, has relinquished his position with the Anne Shaw Organisation Limited, and has taken up an appointment as Production Manager of Mitchells, Ashworth, Stansfield & Co. Ltd., Rawtenstall, Lancs.

Mr. I. Mann, Associate Member, will be taking up an appointment as from the 1st November, as Works Director of The Carborundum Company Limited. He will be in charge of a new bonded coated abrasive factory in Madras, India.

Mr. A. Niedzwiedzki, Associate Member, is now a Metallurgical Engineer with Kearney & Trecker Corporation, Milwaukee, U.S.A. Mr. Niedzwiedzki will be in charge of different problems relating to construction of new machine tools.

Mr. S. E. Parsons, Associate Member, has left Messrs. Mole & De Kock (Pty.) Ltd., and has taken up an appointment with the Rhodes University, Research Laboratory, Port Elizabeth, Cape Province.

Mr. Ralph Parish, Associate Member, has recently been appointed General Manager of The Yorkshire Die-Casting Co. Ltd., Yorkshire.

Mr. N. W. Walker, Associate Member, has taken up an appointment as Chief Planning Engineer with Hosemaster Machine Co. Ltd., Liverpool.

Mr. V. Yarnwood, Associate Member, has been appointed Engineer with Stockdale Engineering Limited, Poynton, Cheshire.

Mr. H. A. Blomiley, Graduate, formerly with Henry Simon (Eng. Works) Limited, has now taken up an appointment with The Lapointe Machine Tool Co. Ltd., Watford, as Technical Representative in the Northern area of the British Isles.

Mr. R. S. Cracknell, Graduate, is now General Manager of Clarke (Dritex) Limited, Leeds.

Mr. S. Jana, Graduate, is now Technical Assistant in the Tools and Methods Section of the Indian Telephone Industries Limited, Bangalore.

Mr. F. G. Little, Graduate, formerly with Worthington Simpson Limited, is now Technical Engineer with Crofts (Engineers) Limited of Bradford.

Mr. John Murgatroyd, Graduate, has relinquished his position as Assistant Engineer with the Champion Reef Gold Mines of India Ltd., and is now Maintenance Engineer with F. Hills & Sons Limited, at their Timber & Plywood Factory at Libreville, in French Equatorial Africa.

Mr. F. B. Pearce, Graduate, has been appointed Technical Assistant II, REME, at Headquarters, Base Workshop Group, Chilwell, Notts.

Mr. W. D. Rance, Graduate, has taken up an appointment as Planning Engineer in the Rolling Division, with High Duty Alloys Limited, at their Wern Works, Neath, Glamorgan.

Mr. F. Smith, Graduate, has recently taken up an appointment as Eastern Counties Representative for the Glacier Metal Company.

Mr. P. H. Trigg, Graduate, has relinquished his position with S. Smith & Sons (England) Limited, and has now joined his father's firm of G. E. Sworder & Son in a consulting capacity .

Mr. R. H. Wall, Graduate, has recently taken up an appointment as Planning Engineer at Hoover Limited, High Wycombe.

Mr. T. Alan Webster, Graduate, has been appointed Assistant Mechanical Engineer with the Research and Development Department of the Superheater Co. Ltd., Manchester.

Hazleton Memorial Library

REVIEWS & ABSTRACTS

Members are asked to note that the Library will normally be open between 10 a.m. and 5.30 p.m. from Monday to Friday each week. It would be helpful if, in addition to the title, the author's name and the classification number could be quoted when ordering books.

Members are reminded that the Library service is available to all members of the Institution and the Librarian is always willing to assist with enquiries.

REVIEWS

"Industrial Engineering": Report of a visit to the U.S.A. in 1953 by a British Specialist Team. *London, British Productivity Council,* 1954. 115 *pages. Illustrations. Diagrams.* 5/-.

The fact that this is the sixty-seventh British Team to pay a fleeting visit to the industrial high spots of America obviously makes it difficult to find and report on anything that the other sixty-six have not already dealt with. It cannot be denied that there is a great deal of higher productivity to be seen and experienced in America, and these Anglo-American visits will undoubtedly have been beneficial, if only in opening wide the eyes of those who have not before seen progressive industry overseas. However, it would appear that we are in danger of comparing the best practice seen in the U.S.A. with the lowest in operation in Britain, but if, as a result of these visits and reports, we can raise the lowest productivity level in Britain to even the average level, it will be a very creditable achievement.

At the risk of being considered over-critical, I would mention that 'first visit goggle eyes' can be almost an occupational disease, and the only real way to find out the industrial atmosphere in a company or country is to earn one's living in it. Once again, a Team has looked for a significant answer to this increased productivity in the U.S.A., but they have discounted the previously suggested reason that the American woman is behind it all as being a symptom and not a cause. They give as significant causes America's historical and geographical position, and the fact that it is a new country in which industry is always expanding; that it is blessed with an ample supply of natural raw materials, and peopled by emigrant settlers eager to make good. These facts could, of course, equally well apply to Canada, New Zealand and Australia. I personally favour the opinion expressed in one report that good salesmanship is the motivating power behind productivity.

The recommendations at the end of Section 1 appear merely to shelve the responsibility on to the other fellow—this time the Government, who are to legislate against monopolies, finance the small firm, increase depreciation allowances, create liberal import licences and, in general, make provision for an easy industrial life.

While I consider that the statement: "We have to report very conflicting evidence on work tempo" requires further elaboration, the Report nevertheless emphasises that high mental and physical energy is mainly the result of a good industrial atmosphere and an environment where the desire incentive has been created by top management not only in the production departments, but in the general office, purchasing, and personnel top managements.

The Team have made three very pertinent points under the heading of "Industrial Policies and the Drive for Improved Methods":

1. There is more ruthlessness with those who fail.
2. Youth is no bar to advancement.
3. Mobility of labour applies equally to executives.

The third point is emphasised by the stressing of the American recognised procedure of a system of job rotation for all executives.

The recommendations at the end of the third section of the Report again appear to pass responsibility to someone else—this time the British Standards Institution, who are to cover the terminology of the whole field of industrial engineering. What a fine job this could be for the Productivity Team to do!

The recommendations in the section dealing with "The Influence of Costing and Financial Control" includes the oft-repeated request for cost figures to be issued more promptly. When will we learn that cost figures submitted even five minutes after the actual material or labour has been used are too late—the money has by then been spent. Surely the financial control takes place before and at the time of the operation, and nothing really effective can be done after the event.

It was interesting to note that the experience of the Team with regard to time study and incentives confirms the combined Report of the Institution of Production Engineers and the Institute of Cost and Works Accountants, issued in December, 1949, i.e., "Interim Report on the Measurement of Productivity".

In reading of the Team's experience with regard to financial incentives, I could hardly agree with their phrase: ". . . the trend away from financial schemes and towards higher basic wages". Surely it is not a trend away, but an evolutionary process towards, which industry has to advance through. Some of these stages are, for instance, 2d. a piece for piece work, individual task rates, group payment by results, team efficiency bonuses, job rating and higher basic rates, and on to monthly wage rewards and perhaps ultimately to annual salary responsibilities. This is emphasised by the Team's further statement: "Meticulous time study and attractive financial incentives were no longer considered sufficient for further advances in productivity". How true all this sounds when we read in the Report: "All the operatives were sitting down waiting to go home 45 minutes before the time for the shift changeover, because they had completed their set tasks".

Under the section headed 'Redundancy", I was amazed to read that the Team recommend "last-in-first-out clauses should be investigated". Every single American industrialist, industrial engineer, manager, foreman and also a large number of American workpeople to whom I have spoken repeatedly expressed

the opinion that the 'seniority ruling' is the worst example of restrictive practice in American industry.

There is no doubt that the Team's reference to the fact that in the United States education on safety is considered more important than safety devices and regulations, is worthy of study, as British industry could be in danger of "guarding itself to death"!

Referring to the term, "Industrial Engineer", it is a little difficult to relate the status of the industrial engineer (i.e., his responsibility and authority as expressed in the Report) to the sample organisation charts presented; in fact, in some of the organisation examples the term does not even appear. My own experience in reviewing many American industrial organisation charts has been that the term "Factory Manager" is much more frequently met with. This title also emphasises management and not engineering.

I believe that the combined report of the I.Prod.E., and the I.C.W.A. on "Measurement of Productivity", issued in October, 1953, gives a good definition of the functions of the industrial engineer; in fact, it goes into the detail of the relative proficiency requirements of the work study observer, the technical engineer, and the industrial engineer.

On reading the sections of the Report dealing with "The Influence of Costing and Financial Control", and "Professional Institutions", I should imagine that the Team's recommendations to the I.C.W.A. to the effect that "since it is only a professional body it loses the advantage of wide membership" and further that "the I.C.W.A. should provide for a wider range of members so that the facilities provided by the Institute are not limited to professional candidates" will meet with mixed comment.

I consider that the Team's main purpose of investigating the dynamic and aggressive American approach to improvement of methods of manufacture and continuous reduction of operating costs has been well fulfilled. In fact, in many ways the Report is a cross-section and a confirmation of many of the previous Anglo-American Productivity Reports. It is in some measure a survey review of the other Reports. The Team have certainly emphasised that there is no substitute for good management and that, in fact, industrial prosperity all depends on good management, whether it is industrial, office, accounting, engineering or trade union management.

This Report can well be recommended to all branches of management for them to read, mark, learn and inwardly digest for immediate and constructive action.

B.H.D.

"Screw Thread Production" by J. S. Murphy. *Brighton, Machinery Publishing Company, Ltd.,* 1953. 2 volumes. Illustrations. Diagrams. £1.15.0. (Machinery's Standard Reference Series.)

The author has collected together in these two volumes the various methods of screw thread production, starting with screw cutting in a lathe right through to thread rolling and centreless thread grinding. These books should prove a real asset to all Production Engineers who are faced with the problem of selecting the most suitable method for any particular job. They would prove particularly helpful when new plant has to be purchased.

The first volume covers in its four chapters screw cutting in a centre lathe; self-opening die heads using radial and tangential chases; thread tapping including tapping attachments and tapping machines, and, finally, thread inspection and measurement.

The second volume covers thread chasing, chasing machines, tap and die holders and collapsing taps; thread rolling with both flat and circular dies; thread milling using single and multi-rib cutters, and thread grinding including centreless thread grinding.

The books are amply illustrated and there is hardly a page without a photograph or diagram of some equipment which is being described in the text. It is clear that the author has an extensive knowledge of screw thread production and also that he has made full use of the machine tool and cutting tool manufacturers in obtaining up-to-date information and illustration.

Unfortunately, there is no information given on thread forms and thread data, and whilst the reason is given for this omission, the books would have been a little more complete had this information been provided.

C.E.

"An Introduction to Cost Accountancy" by R. Warwick Dobson. Volume I. *London, Gee and Company, Ltd.,* 1954. 319 *pages, tables, diagrams.* £1. 15. 0.

This is a scholarly and up-to-date text-book by an expert cost accountant. The present volume is the first of three which, according to the Author's preface, will together cover all aspects of cost accountancy in such a way as to relate together in the one text all the important modern developments in the subject.

Potential readers should not be mislead by the title. This is not an elementary book, even though the Author is doubtless correct in saying that each chapter is but an introduction to its subject, around which a larger work could be written. Nevertheless, anyone who wants to follow the Author in his somewhat leisurely course over a very wide field will find the book very clear and understandable.

The text throughout is in accordance with the agreed terminology of the Institute of Cost and Works Accountants and the Author has everywhere gone to great pains to make his own meaning clear. For example, he starts off by explaining the relationships between the various divisions of accountancy and goes on to examine the relationships between the several sub-divisions of the costing division. The same analytical approach with careful explanation of meaning is apparent in later chapters.

The first volume deals with the theory and basic principles of costing and cost control. Later volumes will deal with the elements of costing and with recording and presentation of costs. For the student of cost accountancy principles, the present volume alone is excellent. Presumably the succeeding volumes will put more emphasis on practical applications and methods and in that light, the three volumes together should be of value to anyone who wants an authoritative text-book dealing with the whole field of cost accountancy.

The present volume brings into focus, each in correct perspective, the various methods of costing—historical, standard, marginal, etc.—but several sections show up particularly well when viewed separately. For example, the portions on depreciation, on variance analysis, and on reciprocal costs are all excellent.

C.H.S.

"Machine Shop Practice: A Text-book for Ministry of Labour trainees, apprentices and technical students" by W. C. Durney. 3rd Edition, *London, Pitman,* 1954. 197 *pages, diagrams.* 12/6d.

The book comprises brief accounts of the usual machine shop processes, detailed accounts of a number of practical machine and fitting shops exercises, and at the end of each chapter, a selection of City & Guilds' examination questions, mainly Intermediate Standard.

J.W.B.

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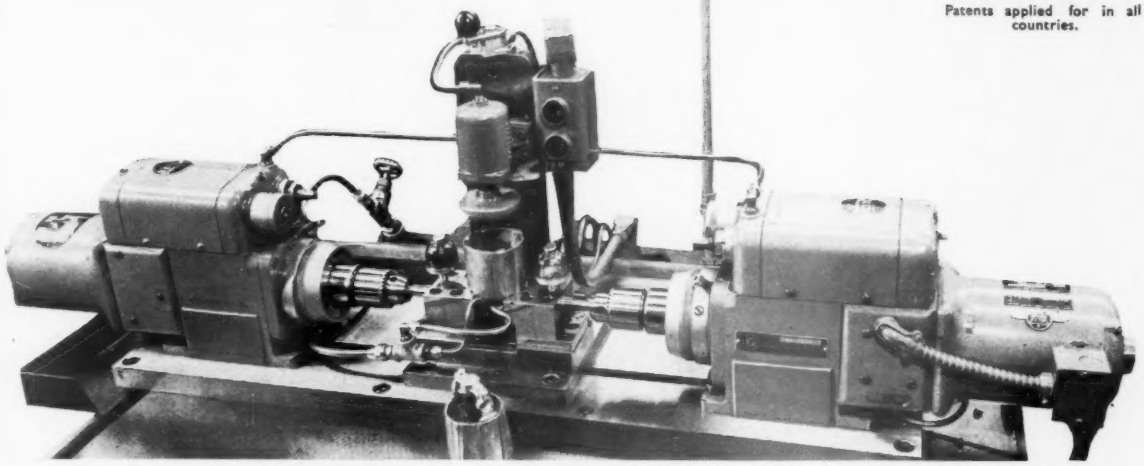


A USER Cuts Production Costs 25% with DELTA Air Hydraulic DRILL UNITS

One user combined two model 19-150 Delta Air-Powered Hydraulic Drill Units and a standard Delta drill press table to build a simplified, single-purpose production machine. Their aim was to increase unit production and cut operating costs.

The principal operation performed on this machine is the simultaneous boring of two brush holder holes in the "Super-Duty" $\frac{1}{4}$" portable drill body. Exacting accuracy is required because these holes are then used for locating the part for all other machining operations on the aluminium castings.

HERE ARE THE RESULTS:

"The Delta hydraulic drill unit has given us more than 25% production savings," says the Superintendent of Production Machining.

Tolerances held are plus .0005 and minus .0000

Average output per hour, 150 bodies. No mechanical, service or maintenance problems, even when the machine has run three shifts for long periods.

Women workers with no previous experience operate the machine.

WHAT'S YOUR SPECIAL PROBLEM?

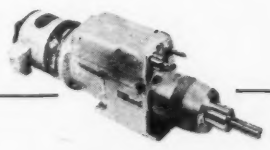
Delta air-powered hydraulic drill units can do for you what they've done for many Users. Our representative will show you how to cut costs with this low-priced, high accuracy, high production drill unit. Our Catalogue suggests many applications. Send for your copy.

DELTA DRILL UNITS ARE MADE IN THREE SIZES:

Capacity in steel up to $\frac{5}{16}$" dia. Drill with 19-150 Unit.

Up to $\frac{5}{8}$" dia. Drill with 19-400 Unit.

Up to 1" dia. Drill with 19-600 Unit.



If you do Production Drilling, Tapping, Outside Threading, Chamfering, Hollow Milling, Counter Boring, Reaming, Centering or Spot-Facing, there is a real probability you can make important savings through improved methods, using Delta Drill Units.

DELTA QUALITY MAKES THE DIFFERENCE

GASTON E. MARBAIX LTD

DEVONSHIRE HOUSE, VICARAGE CRESCENT,
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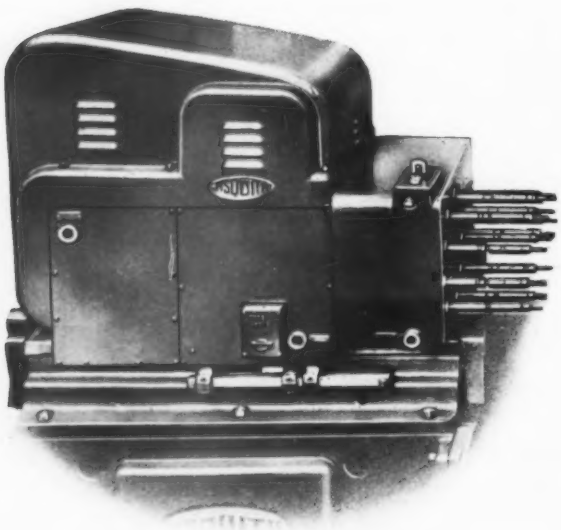
Holemaking

with

MULTI-SPINDLE

UNIT HEADS

for adaptability



ASQUITH Unit Heads are the obvious economic answer where adaptability is an essential feature of production planning.

ASQUITH

WILLIAM ASQUITH LTD. HALIFAX, ENG.

LONDON OFFICE: HALIFAX HOUSE, STRAND, W.C.2.

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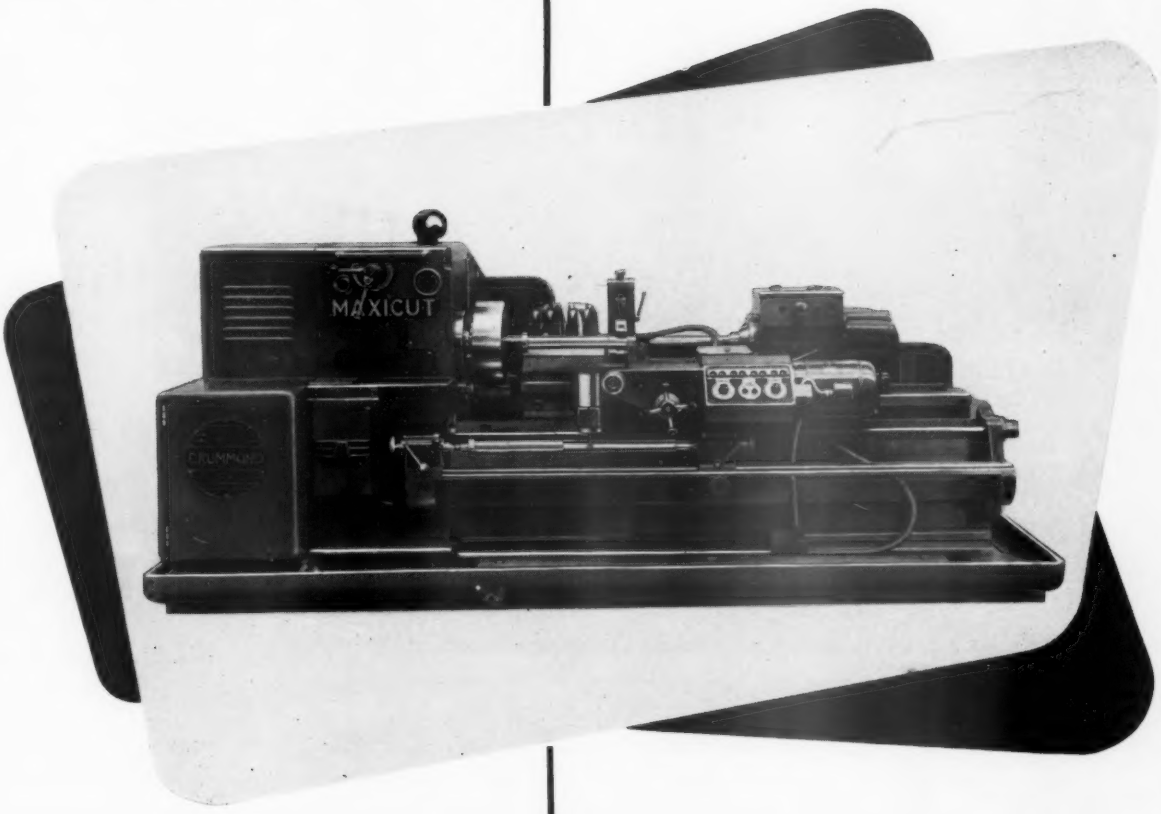
Anderson

Production Turning takes another step forward . . .

MAXICUT MACHINE TOOLS



The MAXICUT Copying Lathe has been developed to deal with a wide range of work in large or small quantities.

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Capacities up to 9" x 78"

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HI-TON

Success Report from the RUBBER INDUSTRY

Photo by courtesy Messrs. The Palmer Tyre Ltd.

Many and varied are the applications of HI-TON presses. Illustrated above is a battery of 6 and 12 ton Pedestal Presses fitted with automatic ram reciprocating mechanism for swaging the ferrules of high pressure flexible pipes. By installing HI-TON the user ensures high output, consistent limits of accuracy and fatigueless clean operation

MODELS FROM 1 TO 250 TONS

HI-TON HYDRAULIC PRESSES

A MODEL FOR ALMOST EVERY NEED

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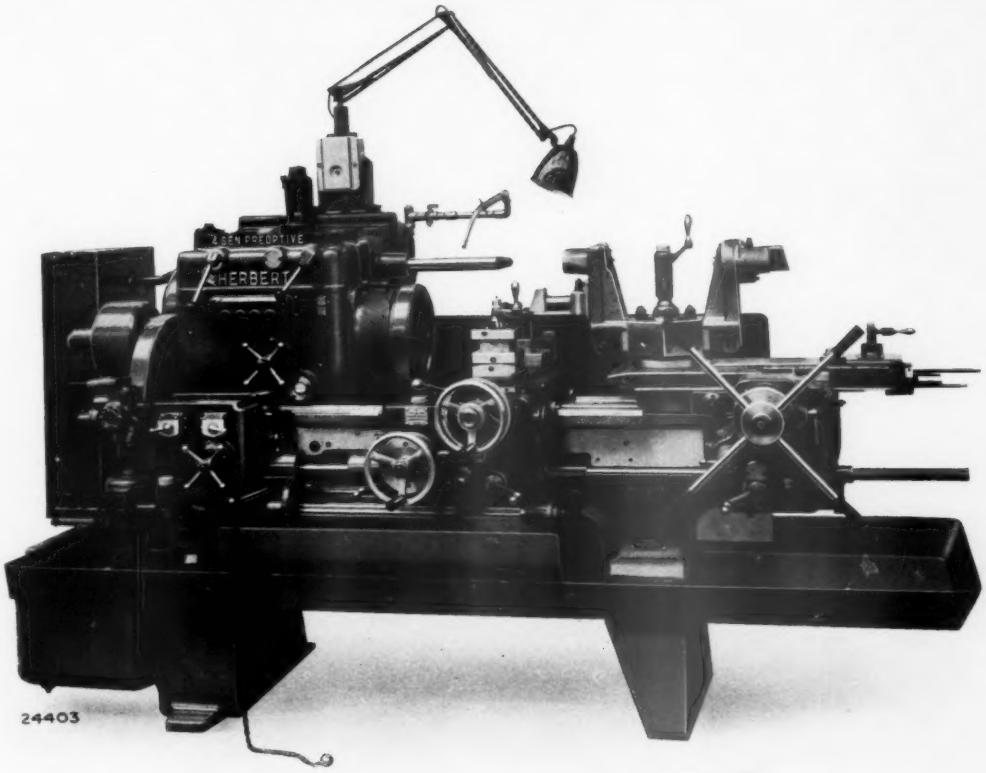
HERBERT



HERBERT No. 4 SENIOR CAPSTAN LATHE

SWING OVER BED 15½" · ADMITS BARS UP TO 2" DIAM.

TO GET INCREASED PRODUCTION

Herbert Capstan and Turret Lathes will relieve your operators of mental and physical effort and so enable them to increase their production.

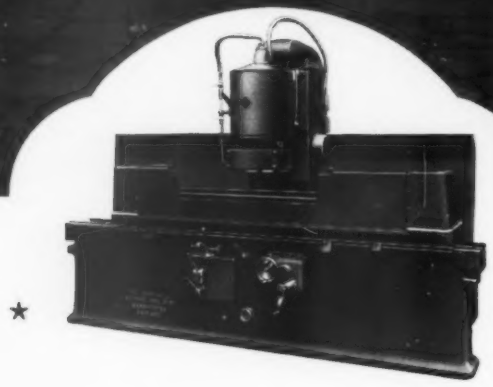
The machines have been carefully designed to provide the utmost convenience in handling and in the changing of speeds and feeds. Large graduated dials make it easy to machine parts to the desired tolerance.

Machines can always be seen in operation at our Head Works.

CAPSTAN LATHES—FIVE SIZES
COMBINATION TURRET LATHES—FIVE SIZES
HEXAGON TURRET BAR LATHES—TWO SIZES

Full particulars on request to Head Works.
'Phone: 88781 (12 Lines)

ALFRED HERBERT LTD · COVENTRY



Avro VULCAN (Photograph by courtesy of A. V. Roe & Co Ltd.)

★

Churchill

By their ability to maintain low limits and fast production rates, CHURCHILL Precision Grinders make an important contribution to the outstanding achievements of the British Aircraft Industry.

★ The CHURCHILL Model 'VXA' 60" x 16½" Vertical Spindle Surface Grinding Machine

THE CHURCHILL MACHINE TOOL CO., LTD., BROADHEATH, Nr. MANCHESTER

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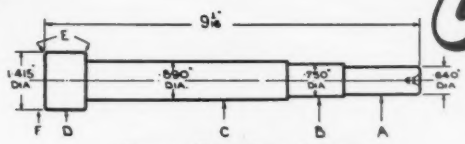
PRECISION *plus* PRODUCTION

C625

For Maximum Production

Ward



Floor to Floor Time: 3 minutes

Nº 3A CAPSTAN LATHE

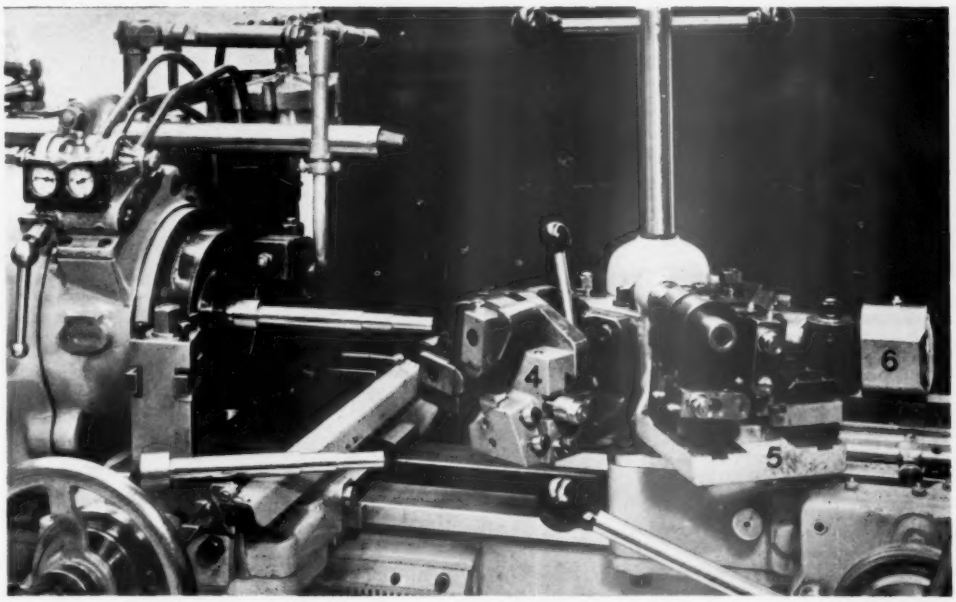
FITTED WITH AIR OPERATED BAR CHUCK AND AIR BAR FEED.

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
Feed to Stop and close chuck	1	—	—	—	—
Centre Drill	2	—	1650	110	Hand
Start Turn two dias. B and C	3	—	1650	620	Hand
Roller Turn C	4	—	954	360	120
Multiple Roller Turn A and B and End	5	—	954	220	120
Turn Head Dia. D	—	Front	954	360	50
Support, Undercut and Double Radius Head E	6	Front	1650	610	Hand
Support and Part-off F	6	Rear	1650	610	Hand

RACK PINION SHAFT

1 7/16" dia. 40 ton Tensile Steel Bar, En.8.

Tungsten Carbide Cutting Tools



Capacity: 1¾ in. dia. hole through spindle. 13⅛ in. dia. swing over bed.
Spindle: Mounted in ball and roller bearings.
Powerful friction clutches running in oil transmit power through ground gears.

OUR COMPLETE RANGE INCLUDES CAPSTAN AND TURRET LATHES WITH CAPACITIES UP TO 35 in. SWING OVER BED AND 8½ in. DIA. HOLE THROUGH SPINDLE.

Full details on request

H.W. WARD & CO. LTD

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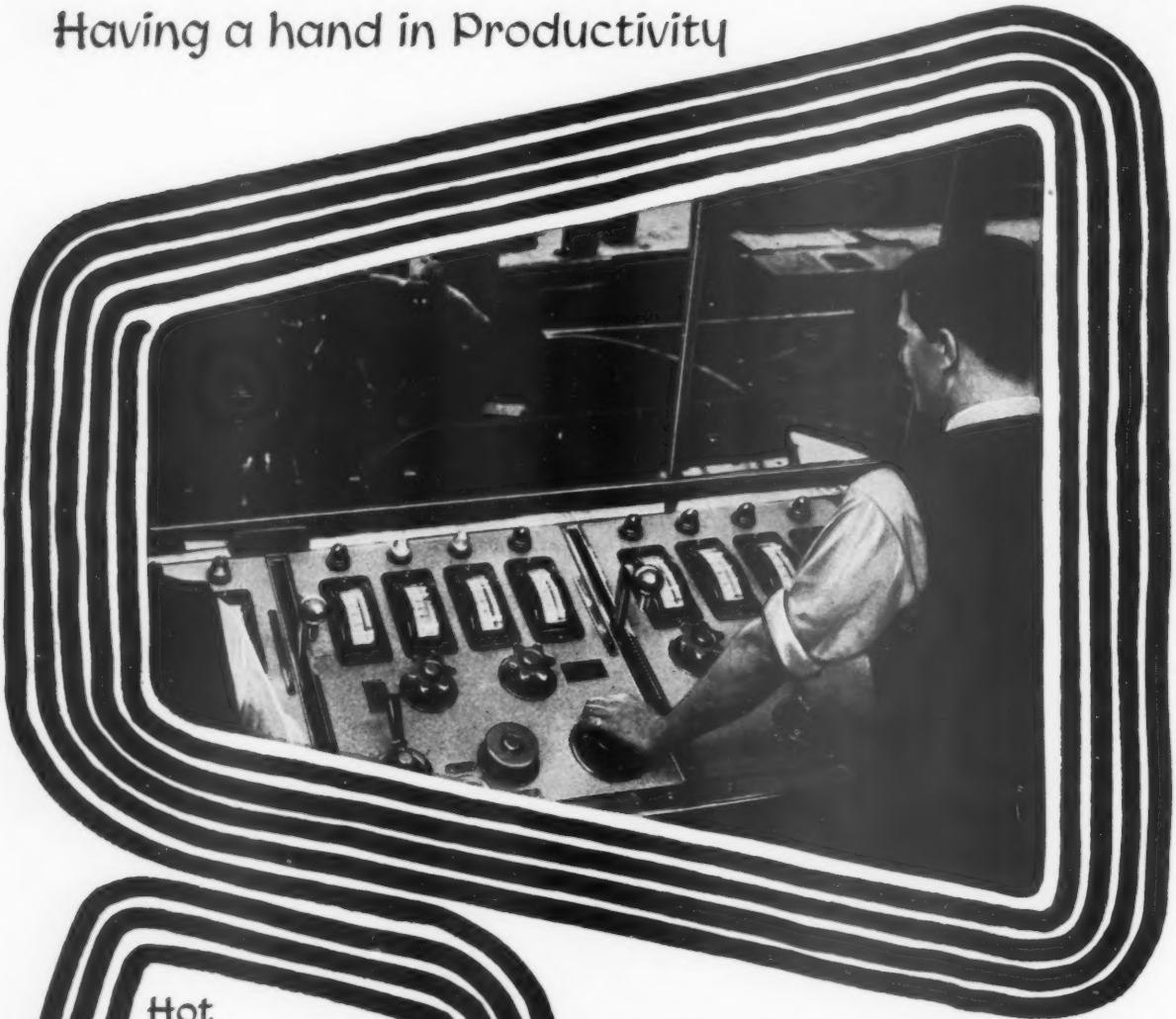
W.615

Having a hand in Productivity



Hot Steel Driver

Scene: a steel rolling mill. Enter: one billet of white hot steel. Action: the billet goes in between the rollers; it comes out thinner but longer; the billet stops, reverses, shoots back. The heavy rollers stop, reverse, accelerate; the steel goes in again, through again, reverses again—and so it goes on. Full speed—stop—accelerate to reverse full speed. All as fast as possible, because increased output is urgently needed. Behind it, one man's hand on a controller. Without electric control, no process even half as fast.

Electric control is
ONLY ONE OF THE AIDS TO HIGHER PRODUCTIVITY THAT ELECTRICITY CAN BRING YOU.

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They can also make available to you, on free loan, several films on the uses of electricity in Industry—produced by the Electrical Development Association.

E.D.A. are publishing a series of books on "Electricity and Productivity". Four titles are available at the moment; they deal with Higher Production, Lighting, Materials Handling, and Resistance Heating. The books are 8/6 each (9/- post free), and the Electricity Boards (or E.D.A. themselves) can supply you.

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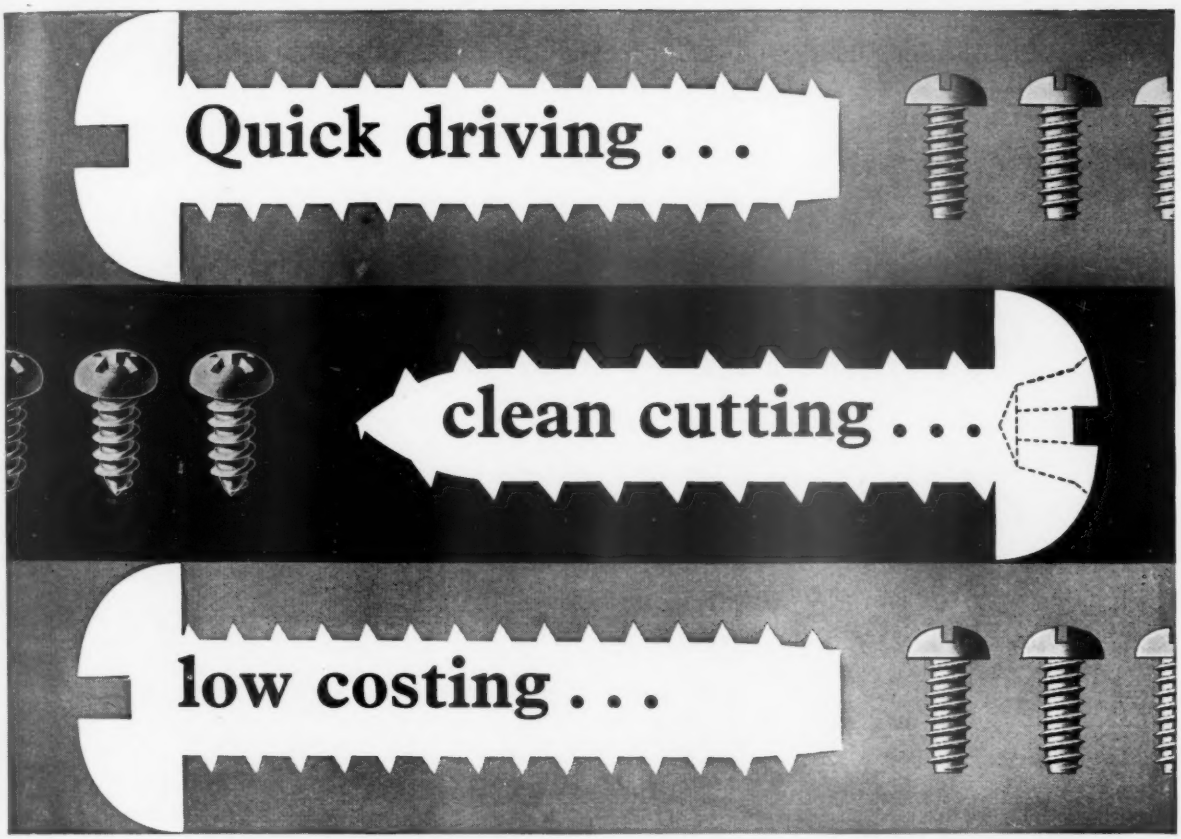

Taps cost money. Tapping takes time. Nettlefolds Parker-Kalon self-tapping screws eliminate both. They cut their own thread and hold securely without the aid of auxiliary fastening devices. There's no risk of broken or stripped screws holding up the assembly line. They can be driven by hand or power.

There are five different types of thread for different materials. The most generally useful being types A & Z which between them cover a wide range of materials from stainless steel to plastics. They are available with all types of heads either slotted, Hexagon, or with Phillips Recess.

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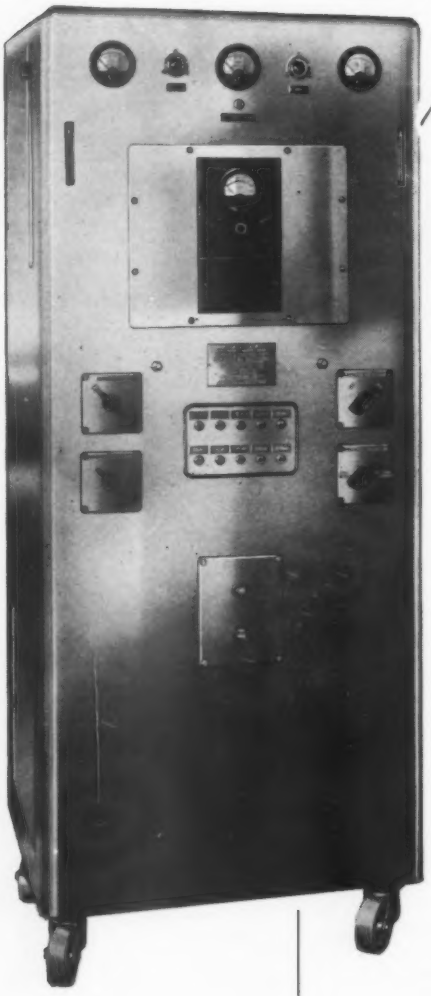

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ARE THE BEST FORM GRINDERS

Spark machining has shown phenomenal savings in many tool room applications using semi-skilled labour. If your problem is complicated shapes and hard-to-machine materials, it would interest you to see our demonstration equipment put to a test on your own particular machining, diesinking or piercing operation.

We illustrate a typical Form Tool made by the Sparcatron Process.

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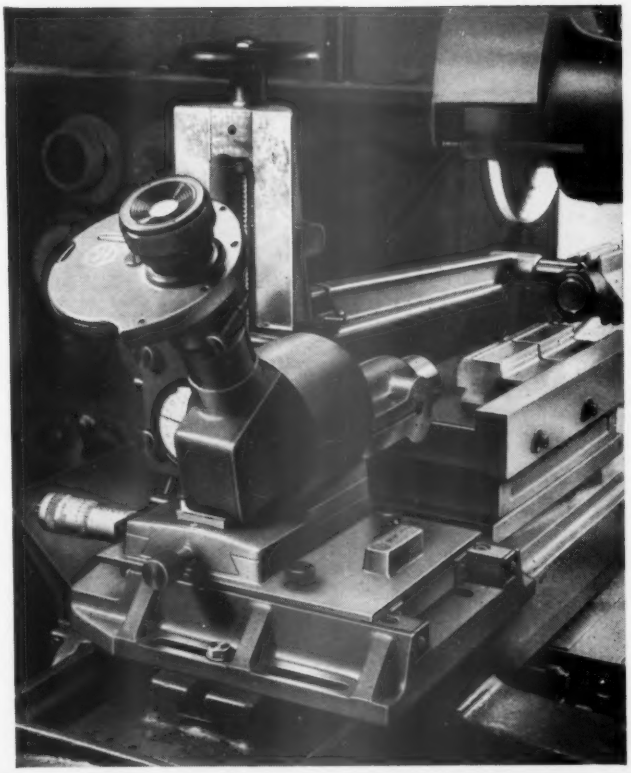
INSTANT CONTROL OF ACCURACY ON PROFILE FORMING!

The 'PG' PROFILOSCOPE has proved highly successful for accurately controlling the forming of irregular shapes and profiles during production. It can be simply applied to many types of machine tools and results in tremendous savings in time and greatly increased accuracy. The turret head holds standard and special graticules according to the form to be produced. Magnification 25x or larger.



THE

PROFILOSCOPE

and the PROJECTORSCOPE

This instrument is designed on similar lines to the Profiloscope, but has a screen in place of an eyepiece. The graticule, workpiece or tool, and grinding wheel, are observed at a magnification of 25x on a 7½" dia. screen.

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A SUBSIDIARY OF GEORGE H. ALEXANDER MACHINERY LTD. 82-4 COLESHILL ST., B'HAM TEL. ASTON CROSS 3264

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Because this vacuum cleaner fan motor housing really is the cat's whiskers. It's light (for the housewife's sake), and strong (to protect the mechanism that goes inside). And we cast the whole complicated thing in one simple operation, by pressure die casting. Can you think of a better way of doing it?

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CRC 24

VANISHED WITHOUT TRACE...

An army that disappeared

In the Spring of 217 B.C., Hannibal, the Carthaginian Commander, crossed the Alps and invaded Italy. He defeated a great Roman Army at Trebia, leaving a hard-pressed Senate to defend a threatened Rome. With considerable difficulty they raised a further 40,000 men and dispatched them under the Consul Flaminius to drive off the Carthaginians. Their choice of a commander was unfortunate, for Flaminius was a hot-blooded, impetuous man of little military ability. To draw him to a battleground of his own choosing, Hannibal after burning and wasting Umbria, then retired along the narrow shore of Lake Trasimenus, dropping off picked divisions into the surrounding hills to outflank the pursuing legions and block their advance. Furious at this ravaging on Roman soil, Flaminius rushed after the Carthaginians. The Romans, in column-of-march, were soon in the trap, and Hannibal's troops, who had been concealed by the dense morning mists and high hills, rushed down and destroyed them. An army of 40,000 men who had marched off along the quiet lakeside into the mist, had *vanished without trace* ere nightfall . . . . . .

COLLEX REMOVES GREASE WITHOUT TRACE

Where Collex is used for degreasing it can be said truthfully that here also, all deposits 'vanish without trace'. Our Laboratories will study any problem and prescribe the correct grade of Collex degreasant to solve it. There are many grades from which to choose, and one of our Technical Representatives will visit you upon receipt of a letter, or a telephone call to **Liberty 1021.**

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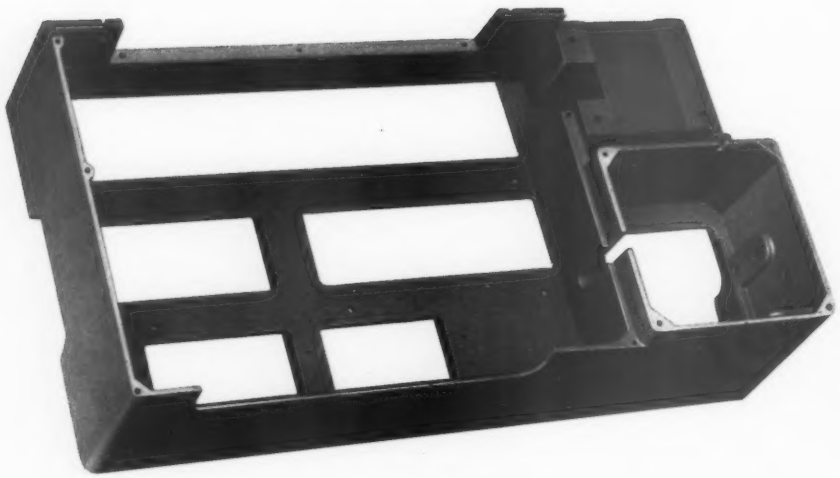
(IN MAZAK OF COURSE)



This is the base of a Recording Machine pressure die-cast in zinc alloy.
We have all the technical knowledge to make such components a profitable die-casting proposition. This knowledge is at your disposal and consultation with us in the early stages will ensure your components being produced in the most cost-saving manner.

30 YEARS' ANGLO-AMERICAN DIE-CASTING EXPERIENCE

WOLVERHAMPTON DIE-CASTING
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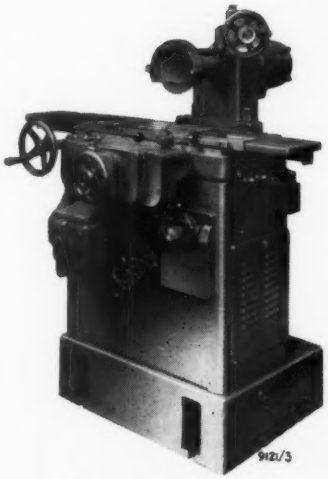
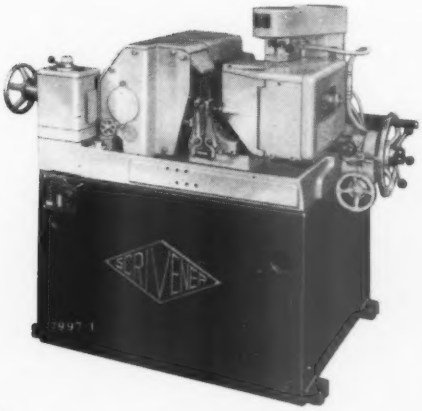
Some Scrivener Grinders



6" x 18" Surface Grinder

Sole selling agents for Great Britain and Ireland except for last-named: Alfred Herbert Ltd., Coventry



No. 1 Centreless Grinder

SURFACE GRINDERS

(Reciprocating table type) Sizes 6" x 18"
8" x 18"

CENTRELESS GRINDERS

Sizes Nos. 1 and 2, Class "D" and "G" the versatile general-purpose models, and the Controlled-cycle automatic or semi-automatic models for plunge grinding.

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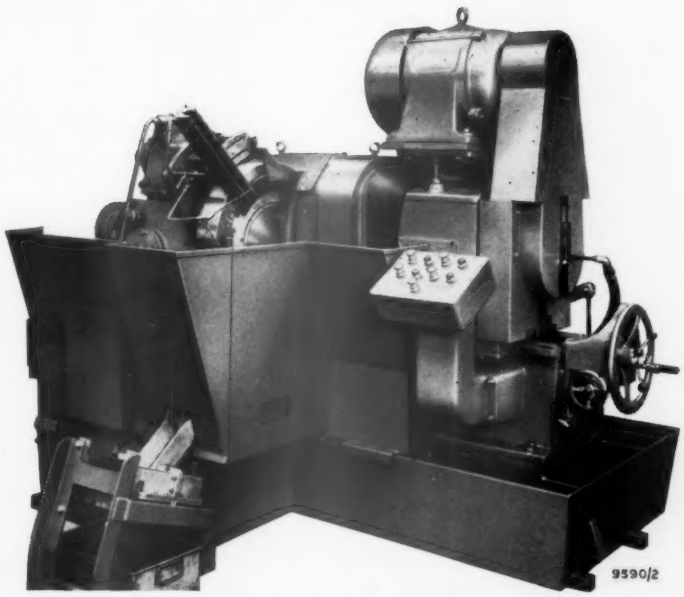
(Horizontal spindle type) for the automatic grinding of two opposing surfaces in a single operation. Nos. 24 and 30.

AUTOMATIC HORIZONTAL ROTARY SURFACE GRINDER

Sizes Nos. 24 and 30.

Catalogues of any of the foregoing upon application.

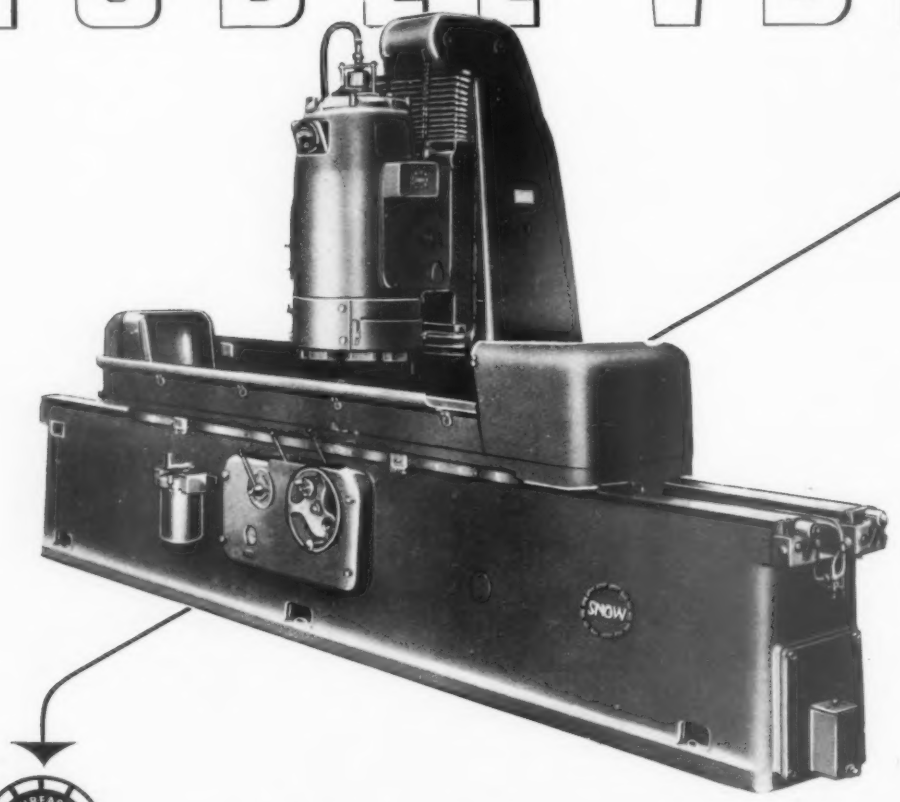


Automatic Rotary Surface Grinder

ARTHUR SCRIVENER, LTD. TYBURN ROAD BIRMINGHAM

Telephone: ERDington 2274 Telegrams: "Machintool"

MODEL VB18



SURFACE SNOW GRINDERS

RAPID AND ACCURATE PRODUCTION OF FLAT SURFACES

THE SNOW VERTICAL SURFACE GRINDERS are capable of continuous and heavy duty on almost all types of material. Hydraulic reciprocation of the worktable gives variable speeds up to 80 f.p.m. with shockless reverse. In design particular attention has been given to the maximum ease of control and minimum of maintenance. Range of sizes: 32 in by 10 in. to 72 in. by 15 in.

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& CO., LTD
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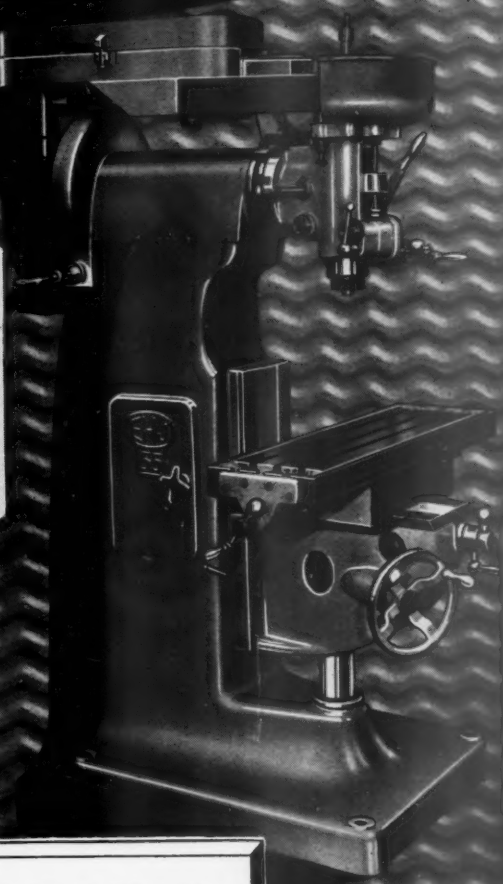
LONDON: 58 Victoria Street, S.W.1 : BIRMINGHAM: Daimler House, Paradise Street

EHJ No. 55 VERTICAL MILLING MACHINE



SPECIFICATION

Table working surface ... ... 32″×11″
Number of speeds 8
Speed range
Low speed machine 100-2450 rpm
High speed machine 150-3650 rpm
Spindle taper ... 3 MT
Drive motor ... 1 HP

EHJ INTRODUCE a new swivelling head Vertical Milling Machine specially designed for high speed milling and die-sinking.

Full specification available on request.

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Rainbow

The Vital

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Made to the exacting quality specification of the world's largest specialist screw manufacturers

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UNBRAKO SOCKET SCREW CO. LTD
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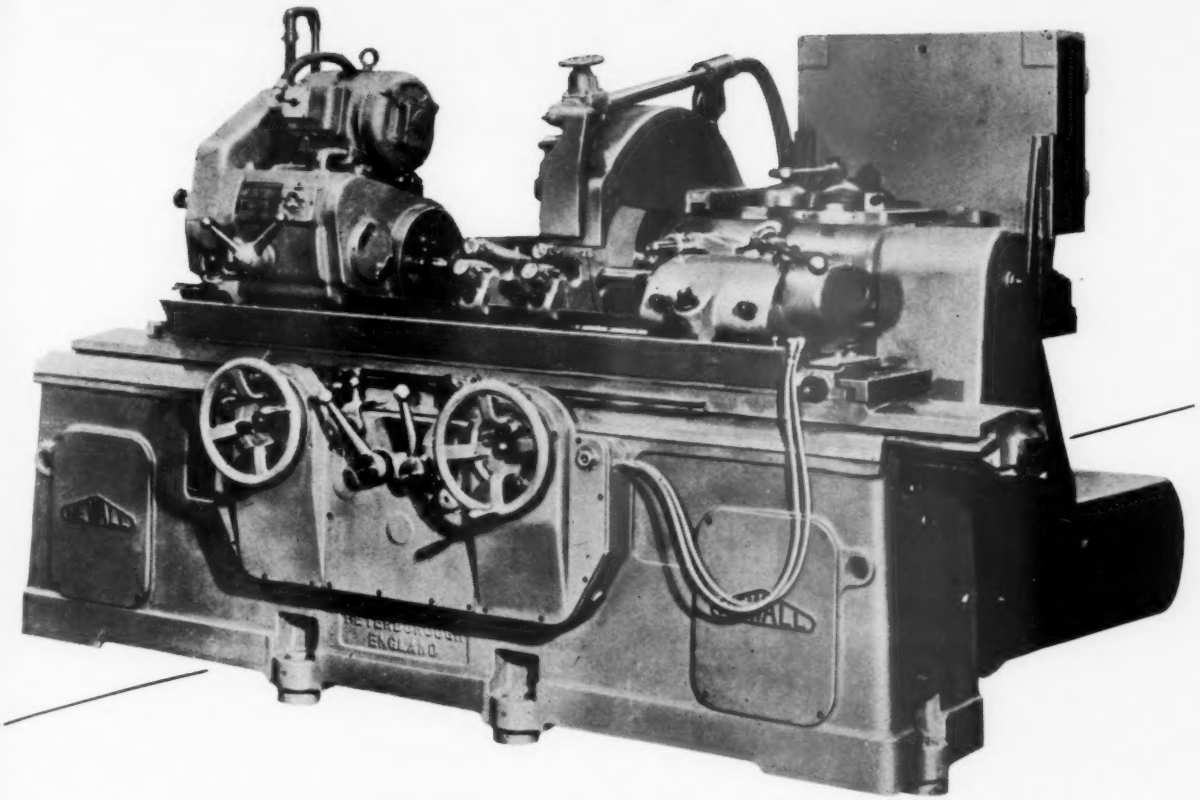

LA cylindrical grinder

FOR SPEEDIER LARGE BATCH PRODUCTION

The Newall LA Cylindrical Grinding Machine is manufactured with centre heights to grind 10" or 16" diameter, with a range of capacities of 24", 36", 48", 60", 72", 84" between centres. The 16" machine (Type HLA) has all the features of the LA, and can swing work up to 16" diameter and grind this diameter with a new wheel.

- **DESIGNED FOR SPEED AND ACCURACY**
- **PRECISION BUILT FOR PROLONGED SERVICE**
- **MASSIVE PROPORTIONS ENSURE VIBRATIONLESS OPERATION**
- **AUTOMATIC WHEELHEAD INFEED FOR PLUNGE CUT GRINDING**
- **AUTOMATIC PRESSURE LUBRICATION THROUGHOUT**
- **ACCURACY OF SETTING AND READING ASSURED**
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A precision product of The Newall Engineering Co. Ltd.

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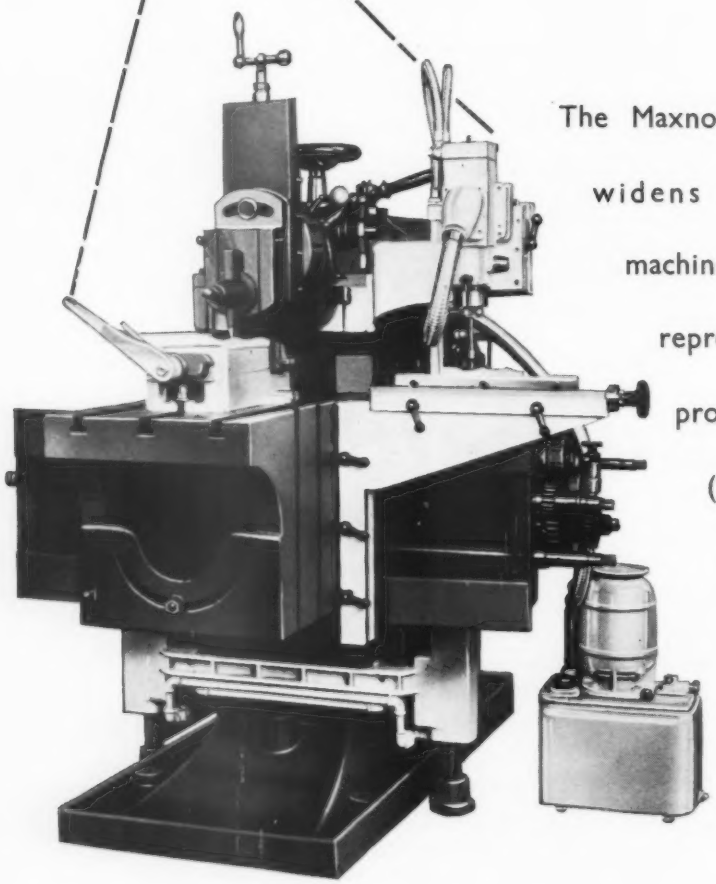
MAXNOVO
DUPLICATING ATTACHMENT
— FOR SHAPING MACHINES —



The Maxnovo Duplicating Attachment widens the scope of shaping machines. It is simple to fit, and reproduces automatically most profiles and square shoulders (90°) where the machine table tilts 30°. Write for full details.

STOCK DELIVERY

● A duplicating attachment is also available for use on lathes.

CATMUR MACHINE TOOL CORPORATION LIMITED

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another **BARBER-COLMAN** *development*

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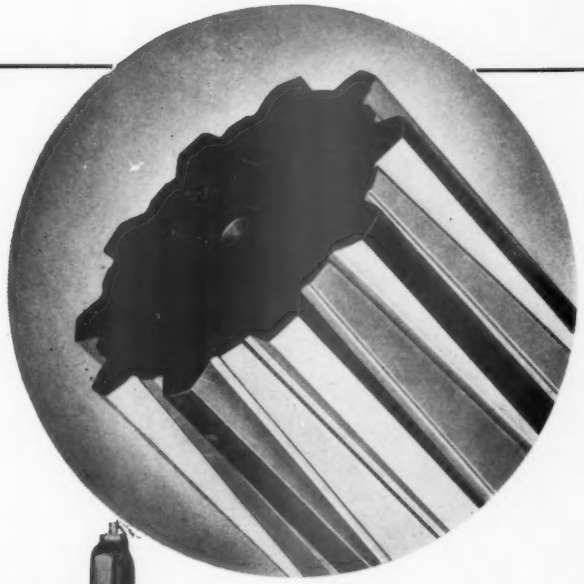

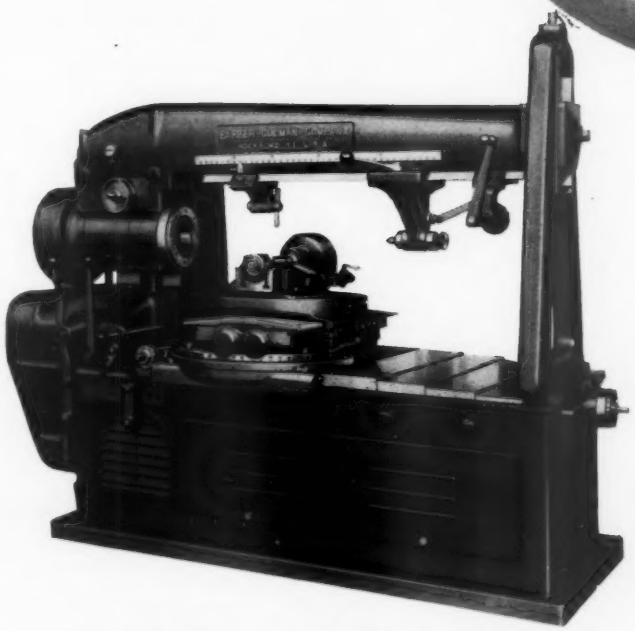

B-C MODEL 16-11 HOBBING MACHINE
Although designed primarily for hobbing taper splines on shafts, this machine may also be used for general purpose hobbing.
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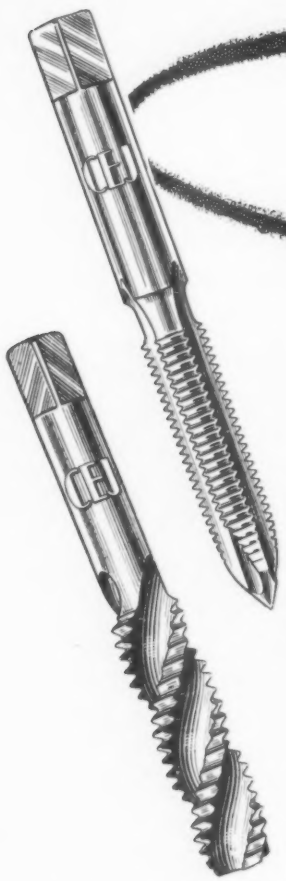

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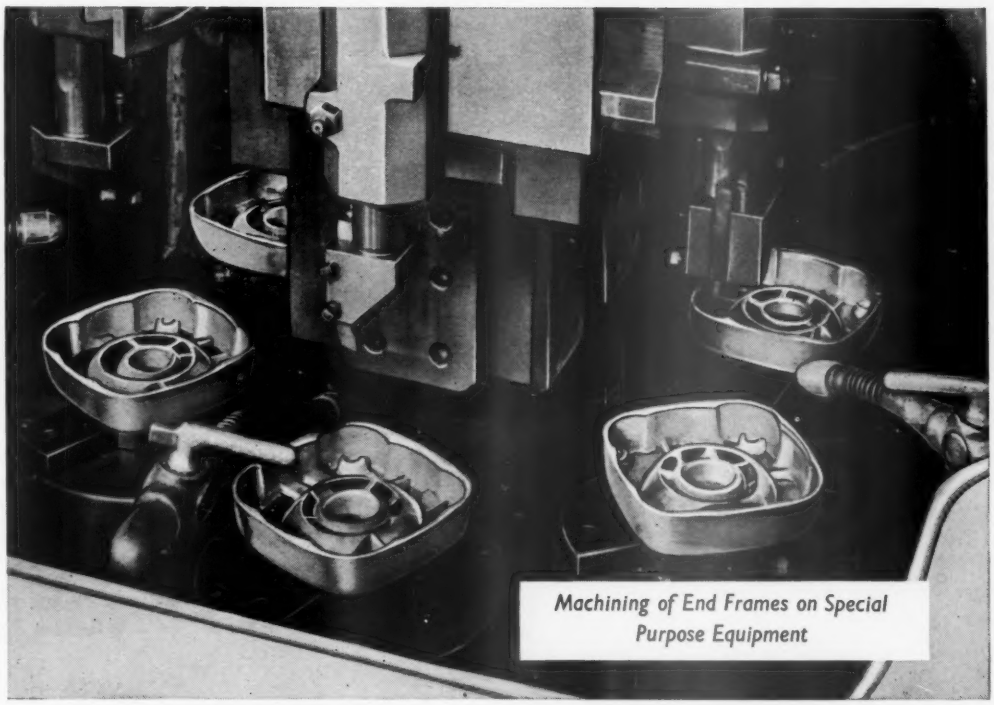

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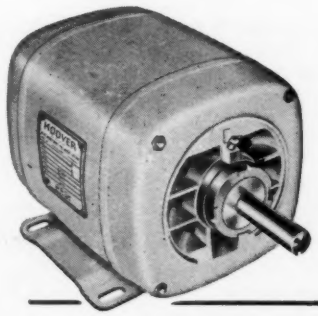

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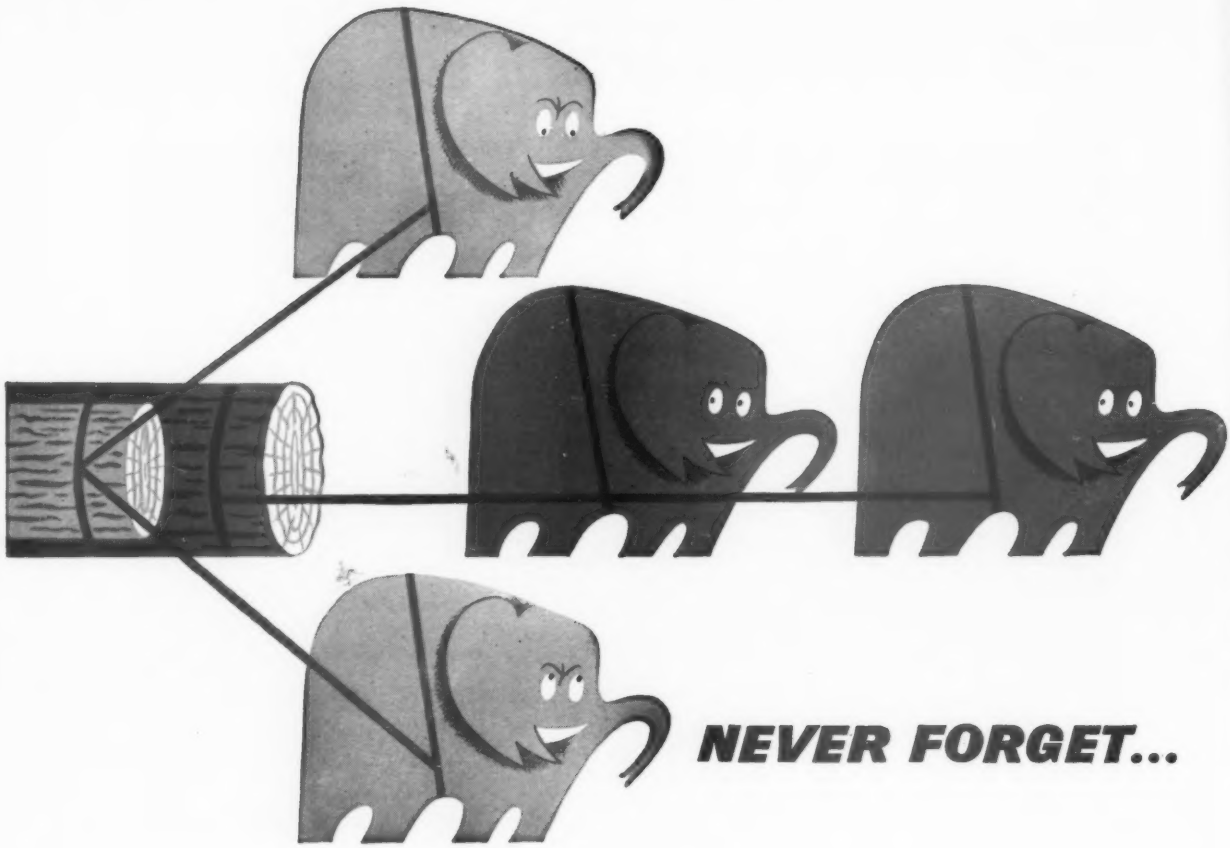

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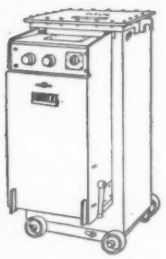

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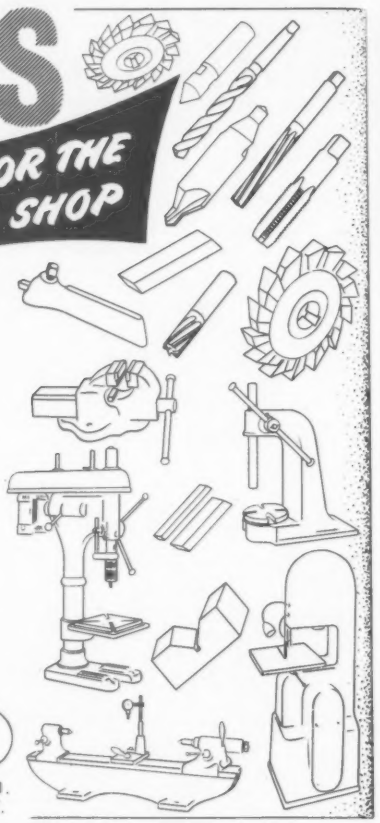

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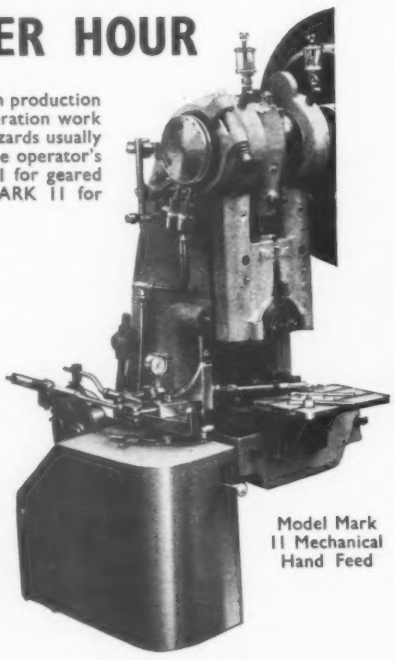

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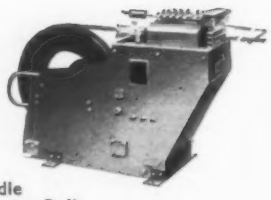

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66

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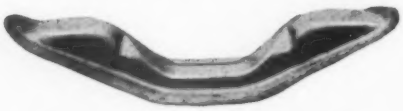

The essence of the process is design. It is open to the Designer to use metal of modest thickness which by skilful manipulation can be formed into a shape through which the forces acting upon a component are resolved along the planes of maximum resistance.

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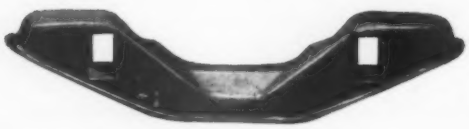

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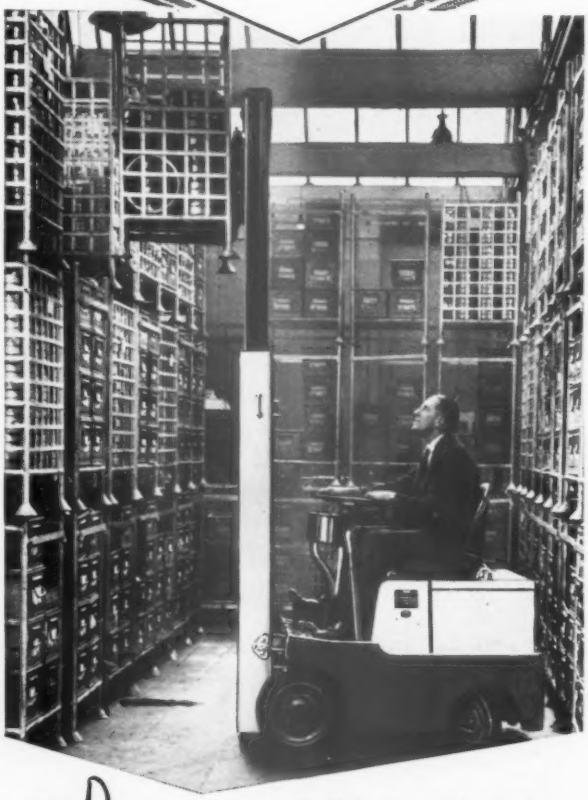

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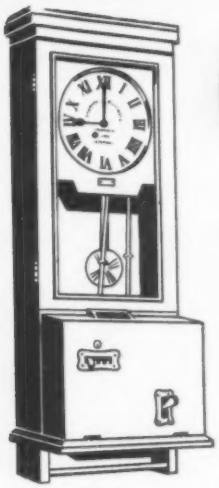

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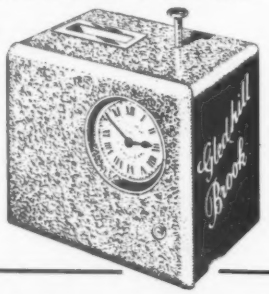

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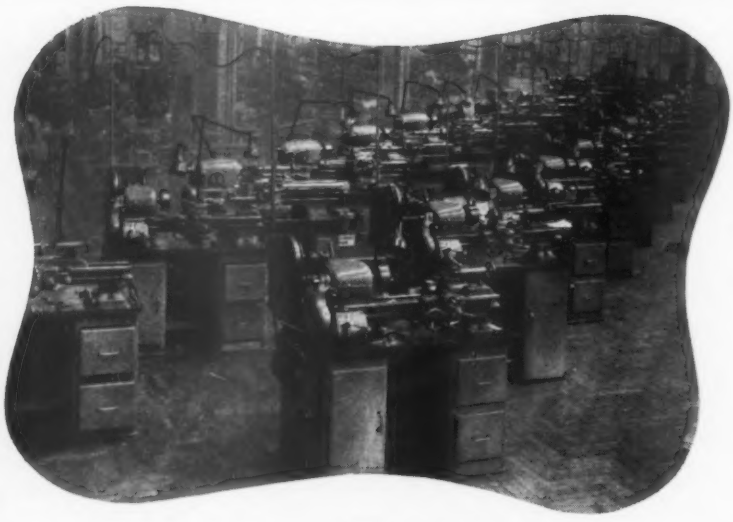

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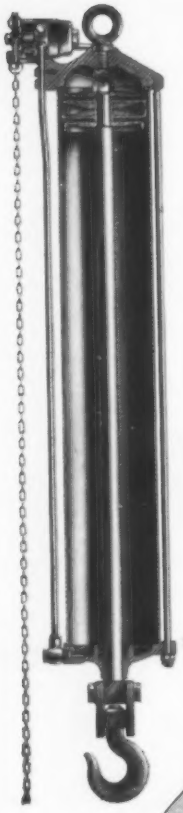

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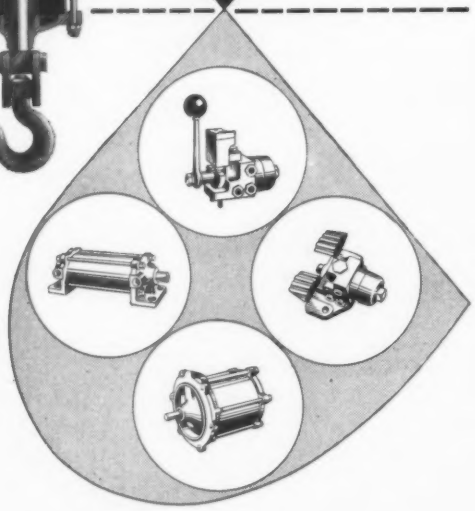

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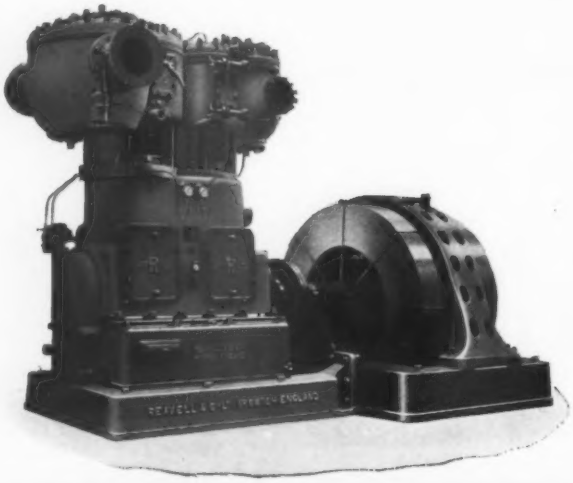

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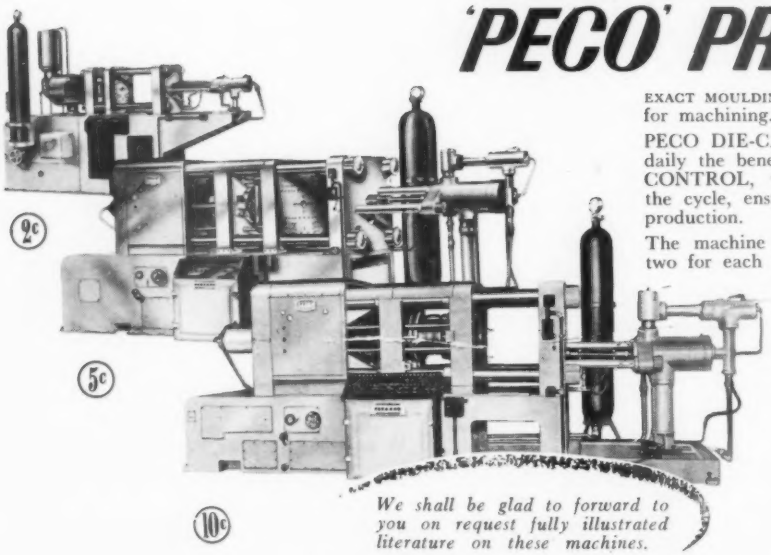

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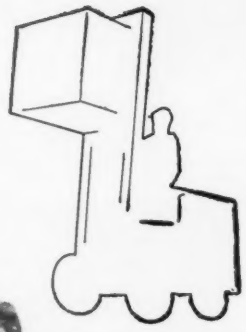

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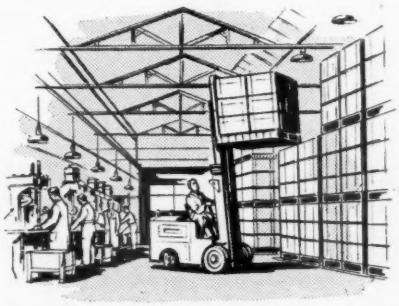

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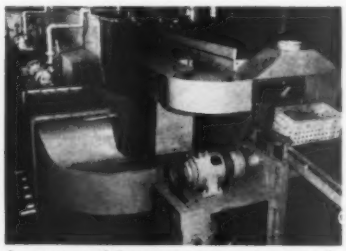
HERE ARE THREE EXAMPLES

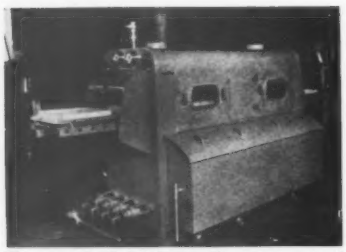
INDUSTRIAL CLEANING MACHINES

can be designed to meet your particular cleaning problems

This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.



A power driven conveyor system is employed with this cleaning machine for ball bearings.



Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

Designed and Manufactured by **BRATBY & HINCHLIFFE LTD · SANDFORD STREET · ANCOATS · MANCHESTER 4**

SOLE AGENTS FOR GREAT BRITAIN

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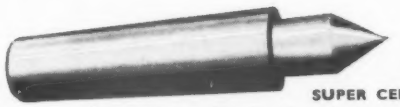
BE RIGHT IN THE CENTRE



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THE OPERATION

Using an auxiliary Power Driven Rotary Table Attachment, dies for circular Pyrex dishes are cut accurately and automatically and with the minimum of operator attention after the original setting of the work (left) in relation to the master (right).

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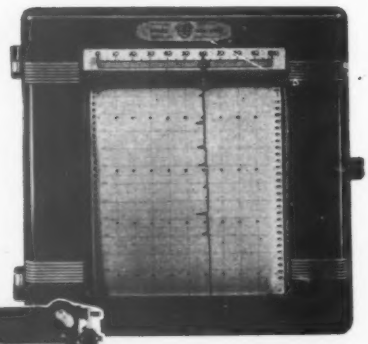

Ether Ltd., use Burgess Micro Switches for electrical control in this and their other high quality products because—like all manufacturers of repute—they believe in having the best component equipment obtainable

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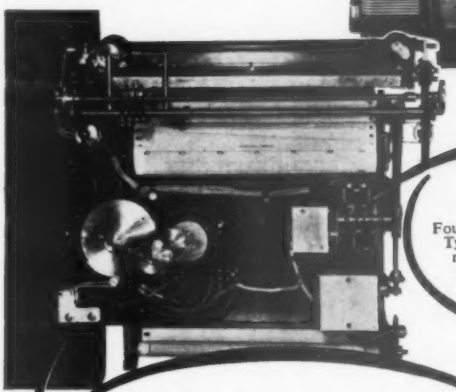

Four Burgess Micro Switchettes, Type V3 fitted with auxiliary roller actuators type VLR1. They switch over two thermo-couples to the amplifier circuit.

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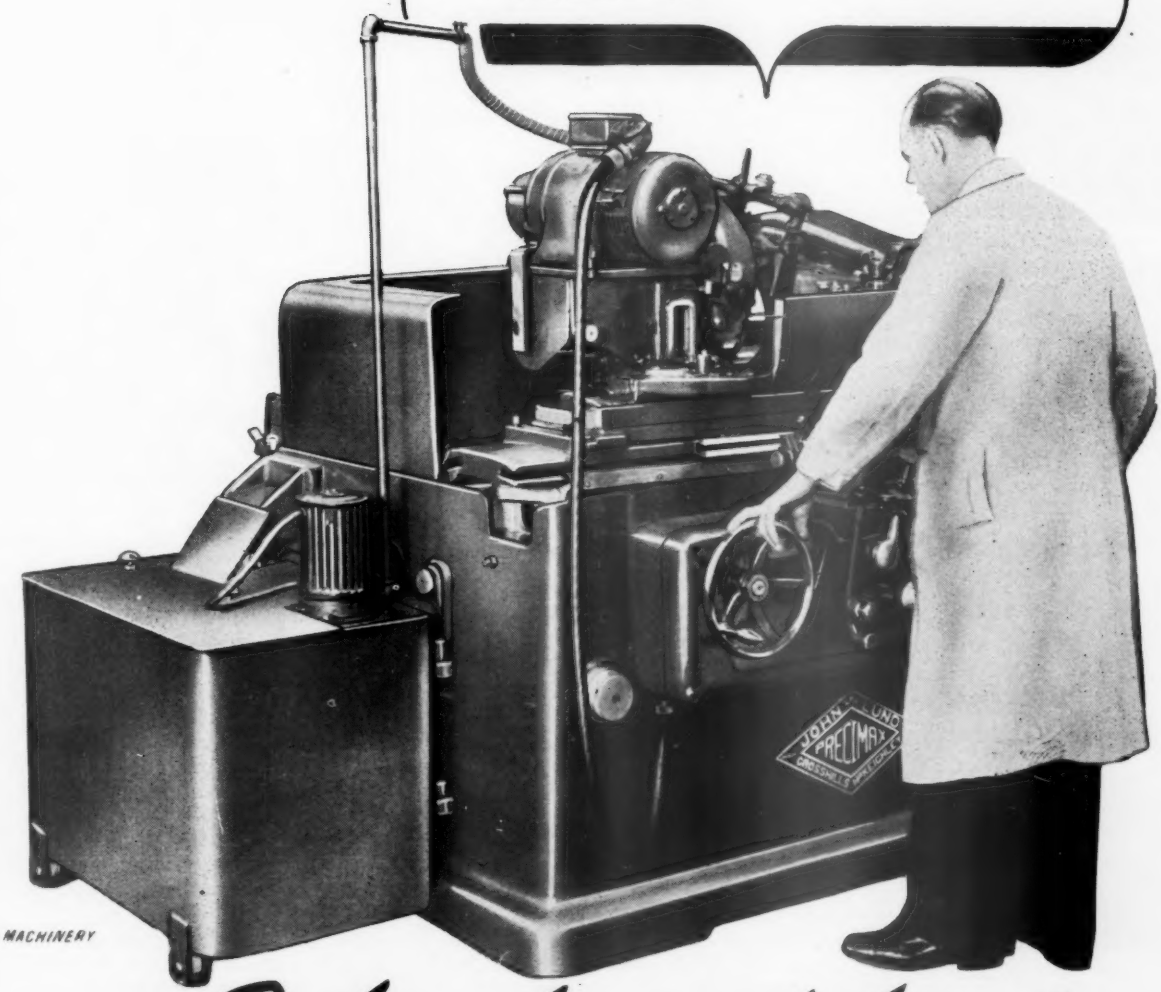

MACHINERY

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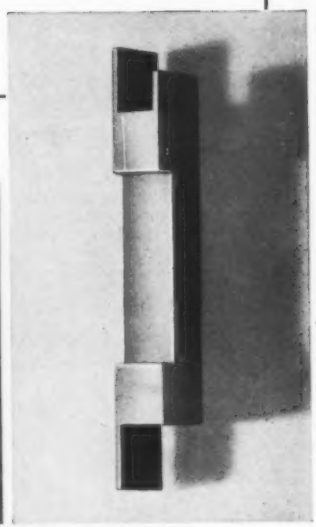
CROSSHILLS · KEIGHLEY · YORKS

If the Managing Director looks at these he will see more than meets the eye



Two views of a cable bridge in 18/8 stainless steel

Trip lever in 18/8 stainless steel

Component for shoe stapling machine in Nitriding steel

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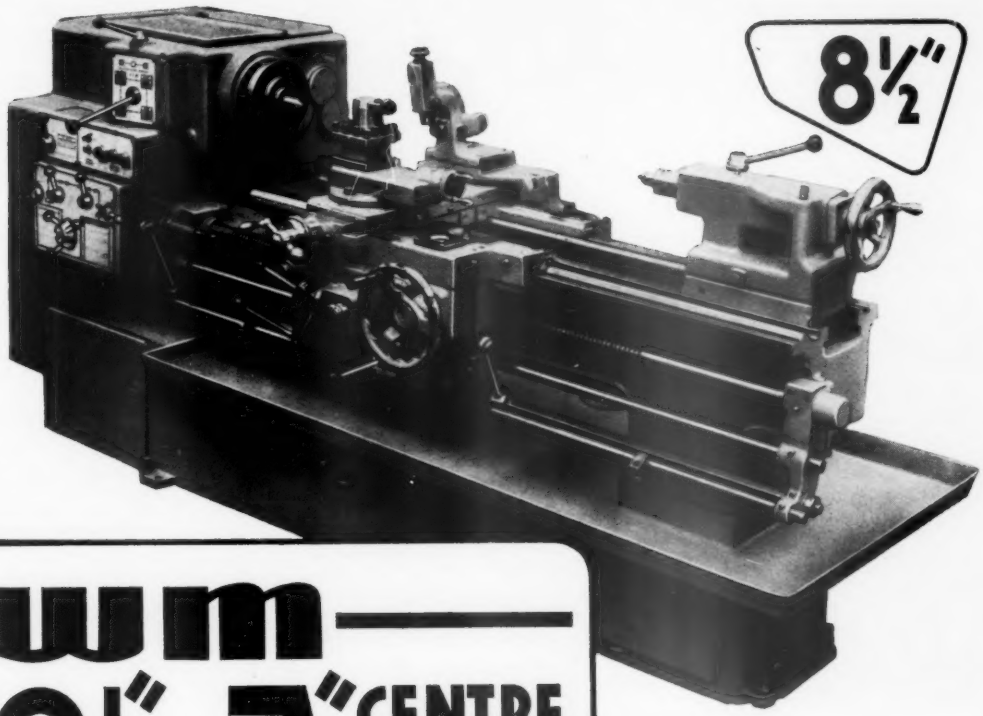

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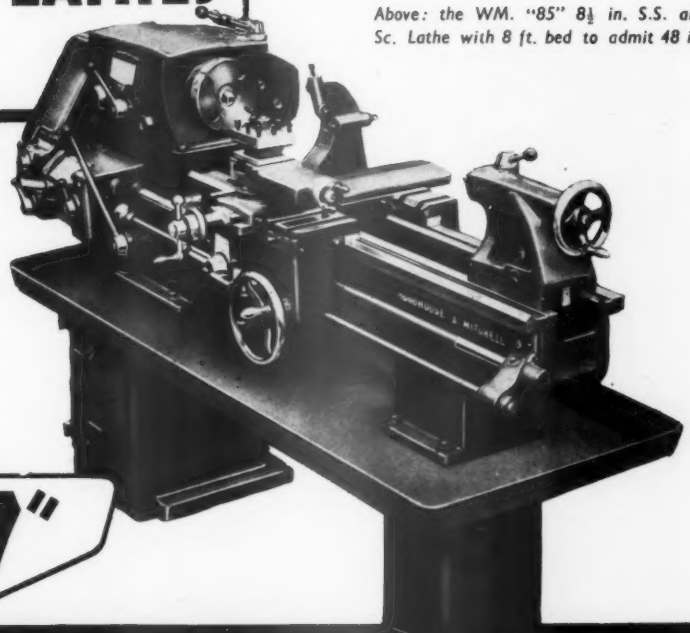
Above: the WM. "85" 8½ in. S.S. and Sc. Lathe with 8 ft. bed to admit 48 in.



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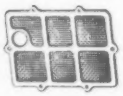
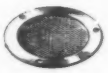
. . . . consult the specialists with  your own filtration or straining problem. For over 25 years Intermit have produced to  customers' own requirements for thousands of different applications.

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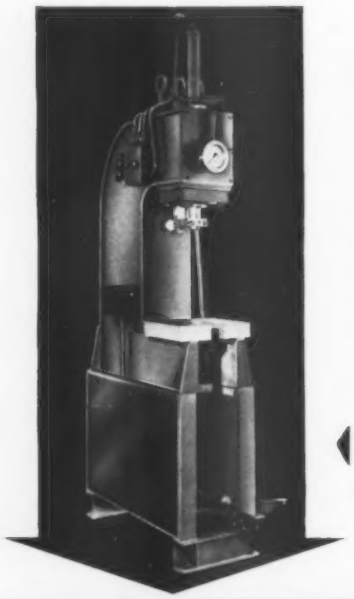

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£240 EX WORKS BOLTON.

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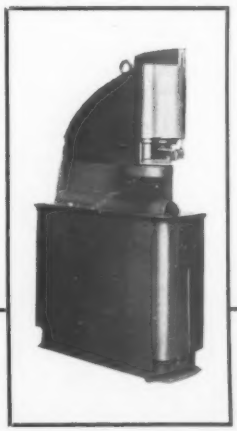

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The Pilot Hydraulic Cropping Machine weighs only 5 cwt. and develops up to 17 tons pressure on the shear blade. The fully automatic operation, with foot control, gives a maximum cutting speed of up to 34 cuts per minute.

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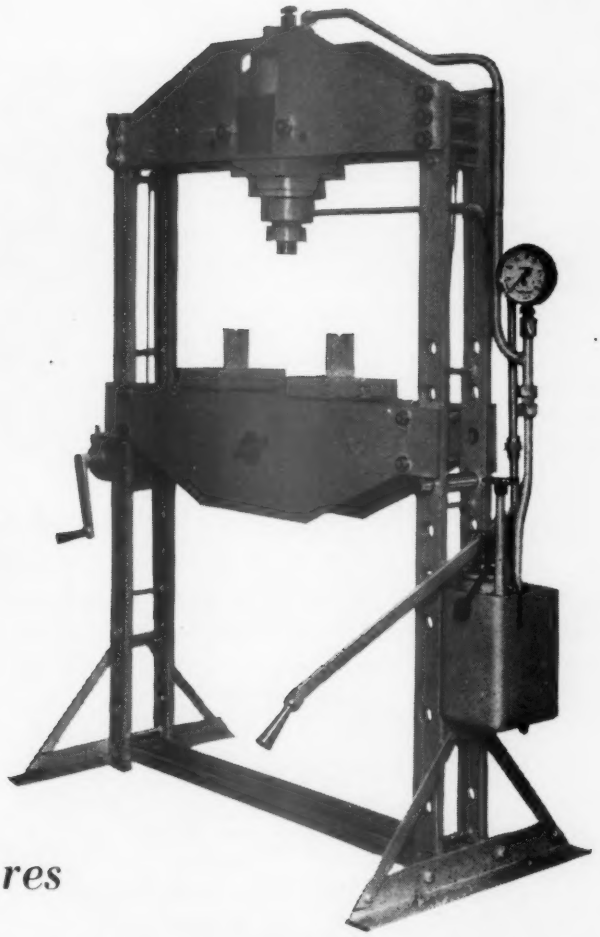

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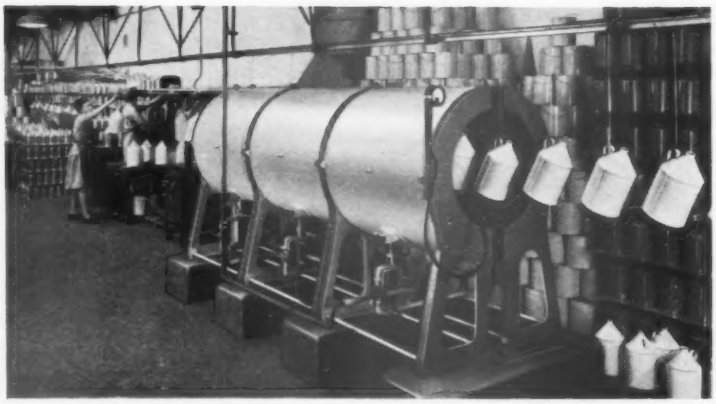

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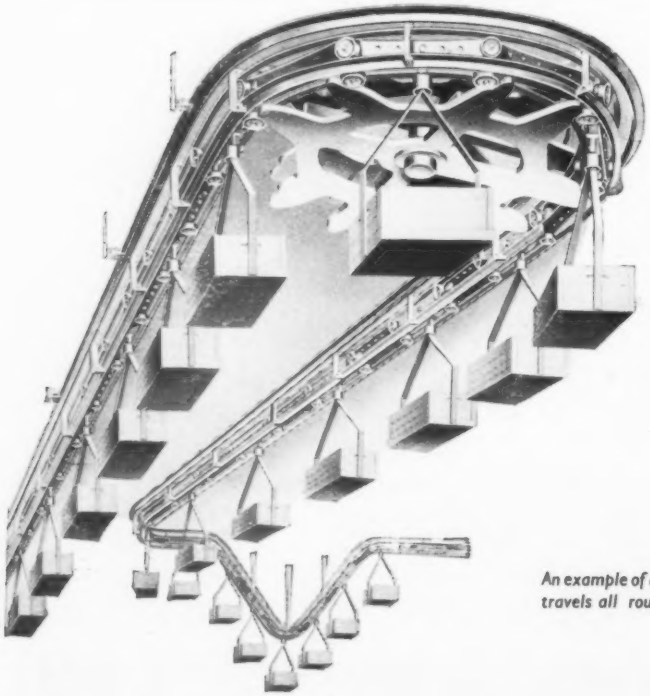

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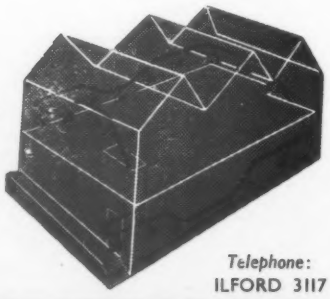

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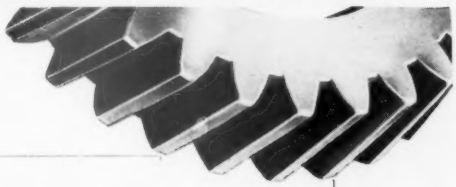

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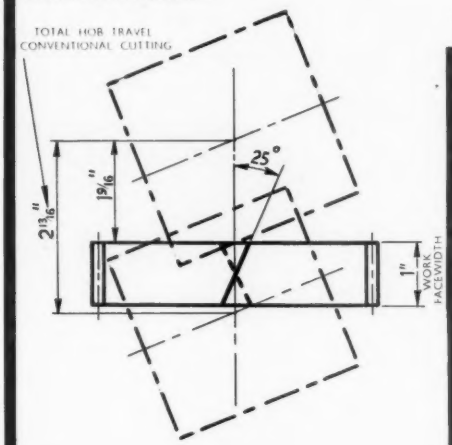

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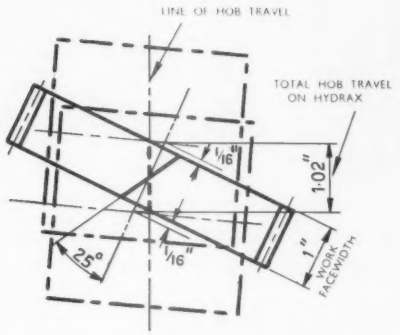

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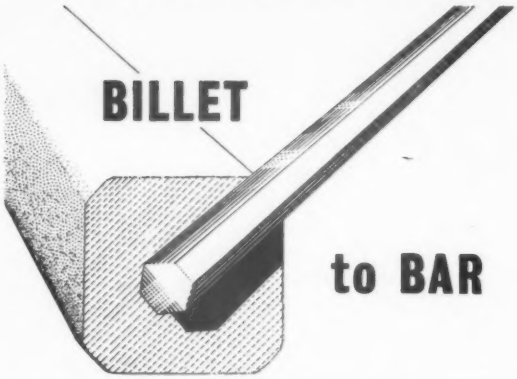

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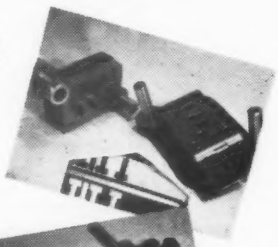

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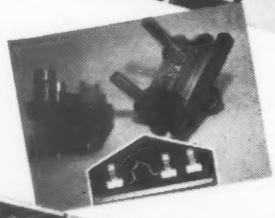

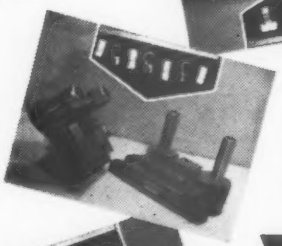

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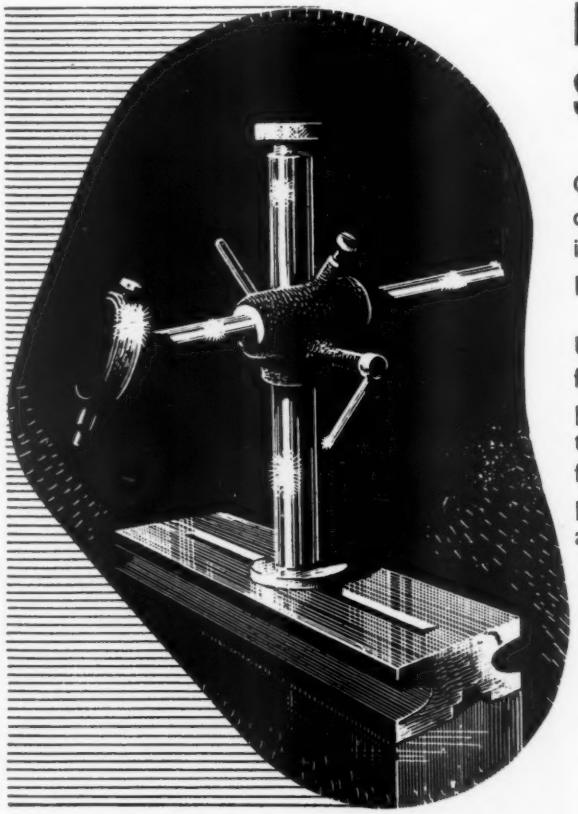

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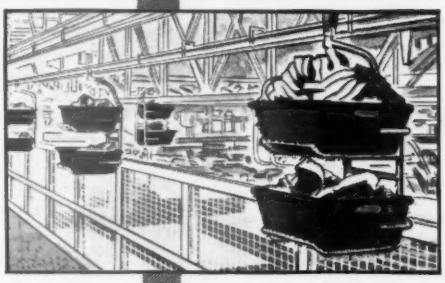

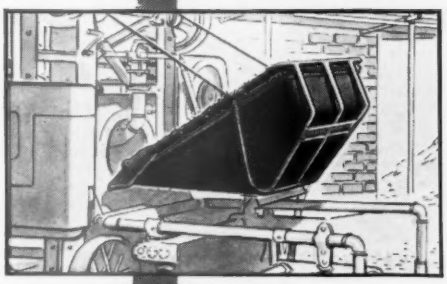

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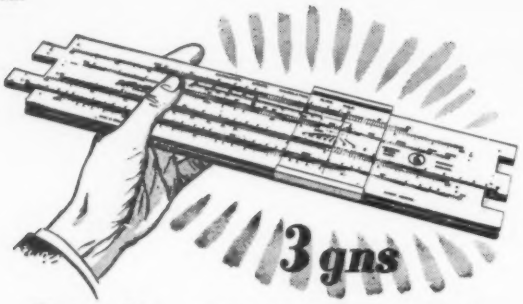

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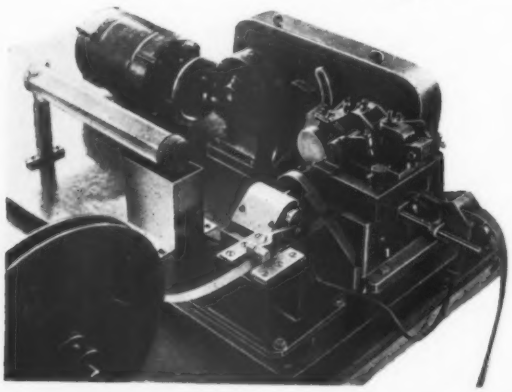

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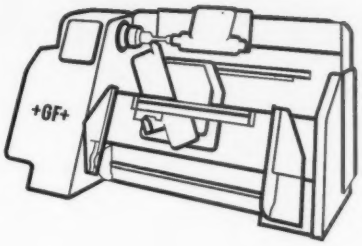

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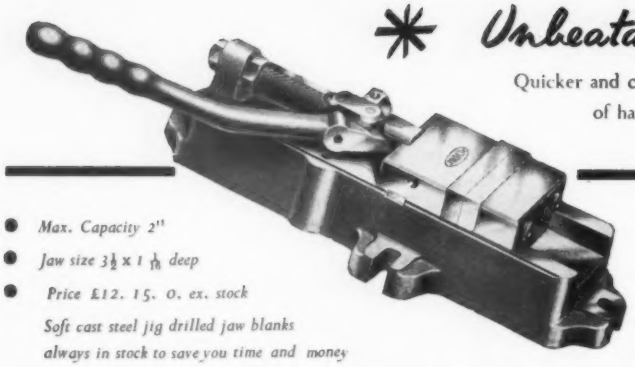

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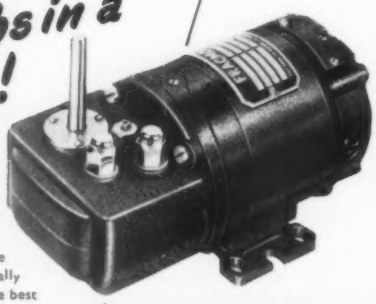

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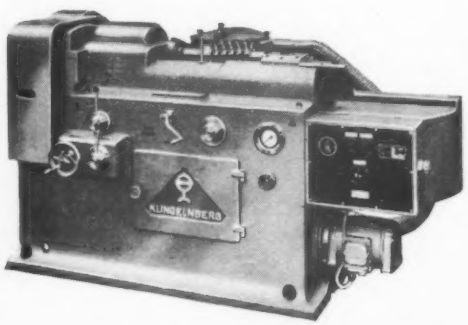

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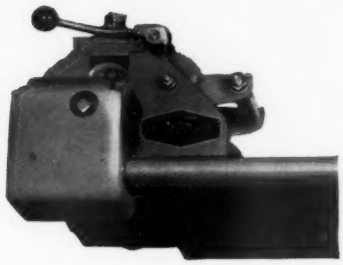

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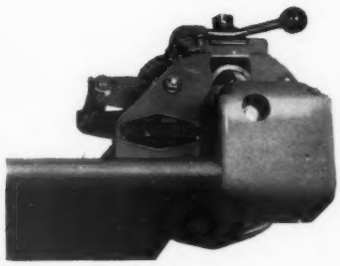

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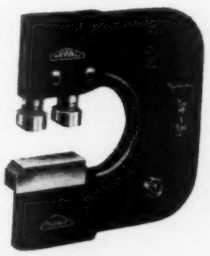

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JOURNAL SUPPLEMENT

Vol. 33, No. 10
October, 1954

INSTITUTION OF PRODUCTION ENGINEERS, 10, CHESTERFIELD ST., LONDON, W.1

THE VISCOUNT NUFFIELD PAPER, 1954

The 1954 Viscount Nuffield Paper will be presented at the Royal Institution, London, on 9th December, 1954, by Major-General W. A. Lord, C.B., C.B.E., Director of Mechanical Engineering at the War Office.

General Lord will take as his subject the vital importance of the application of modern production technology and management to the work of the Corps of Royal Electrical and Mechanical Engineers.

Full particulars of the meeting, together with an application form for tickets, will be published next month.

MATERIALS HANDLING CONFERENCE "TO—THRO'—OUT"

In their investigations into materials handling practice in Britain, the Materials Handling Sub-Committee of the Institution have been concerned at the lack of subject matter on handling which is useful to the smaller firm. A great deal of the information and publications available are applicable only to large concerns, and it is one of the primary aims of the Sub-Committee to do what they can to remedy this deficiency.

As a contribution to this end, a one-day Conference has been arranged, under the auspices of the Sub-Committee, and will be held at the works of John Wright & Company (Radiation), Ltd., Aston, Birmingham, 6, on Saturday, 23rd October, 1954. The Institution is indebted to J. Ivan Yates, Esq., Chairman of Radiation, Ltd., for extending the hospitality of the Company and full facilities of their offices and works for this important Conference.

The theme of the Conference is "TO - THRO' -OUT" - the handling of materials and components TO the factory, THRO' the factory, and OUT of the factory. The programme, which will allow time for free discussion and interchange of information, will include Papers on the following subjects:

(1) "Bringing Materials to the Works"; (2) "Bringing Materials to the Work Station—Development and Application of a Materials Handling System"; (3) "Handling at the Work Station"; (4) "Removal of the Job, Swarf, and Scrap".

Admission to the Conference will be by programme only (price 5/-), which may be obtained from Head Office, using the form overleaf.

AIDS TO PRODUCTION WORK STUDY

A course of six lectures has been arranged at Darlington Technical College for those who, holding positions of some responsibility, wish to study problems of work study.

The first lecture will be held on 14th October, 1954, and the last in the series on 23rd December, 1954. The fee for the course is £1. 1. 0. Full particulars may be obtained from the Principal of the College.

EUROPEAN PRODUCTIVITY AGENCY SCHOLARSHIPS

It is announced by the British Institute of Management that they have been asked by the Board of Trade to undertake the administrative responsibility for the selection and nomination of candidates for four scholarships being awarded under the auspices of the European Productivity Agency.

Candidates, who will leave for the United States of America early in 1955, should preferably be in the age group 35/45; hold a university degree of recognised value or, alternatively, have had extensive training experience; have held a responsible appointment in the business or educational world. Each

participant, or his employing organisation, will be required to pay his fare to and from New York and to contribute $300 (about £107) towards his expenses. Travel subsistence and tuition fees in U.S.A. will be provided.

Members or firms who wish to nominate an individual who could be released to take such a course should write to the Director, British Institute of Management, Management House, 8, Hill Street, London, W.1. (Telephone GROsvenor 6000, Extension 3), as soon as possible, as details of nominees have to be sent to Paris by 15th October, 1954.

To: THE SECRETARY,
THE INSTITUTION OF PRODUCTION ENGINEERS,
10, CHESTERFIELD STREET,
LONDON, W.1.

I wish to attend the Materials Handling Conference which is to be held on Saturday, 23rd October, at the Works of John Wright & Company (Radiation) Limited, Aston, Birmingham, 6. Please send me a copy of the programme, for which I enclose 5/-.

NAME.....

ADDRESS.....

.....

NOTE: No acknowledgment will be made of this reservation. Programmes will be distributed as soon as possible. Cheques and Postal Orders should be made payable to The Institution of Production Engineers.

WORK STUDY SOCIETY CONFERENCE

A One-Day Conference for Directors and Senior Managers has been arranged by the Work Study Society and will be held in the Connaught Rooms, London, on Thursday, 14th October, 1954.

The programme will be as follows:

"The Need for Work Study" by Mr. Bertram White, M.I.Prod.E., Director, A. Boake Roberts & Co., Ltd.

"Work Study Techniques" by Mr. L. G. Humble, Central Work Study Department, I.C.I., Ltd.

"Trade Union Attitudes to Work Study" by Mr. G. E. Dearing, M.B.E., District Secretary, National Union of Hosiery Workers.

"One Management's Experience of Work Study" by Mr. T. A. Mason, Technical Director, Clayton Aniline Co., Ltd.

Tickets for the Conference are £2. 2. 0. each, including luncheon, etc., and may be obtained from the Conference Secretary, Mr. J. A. Mountford, c/o. Brand & Co., Ltd., Mayfair Works, Vauxhall, London, S.W.8. Cheques and Postal Orders should be made payable to The Work Study Society.

PRODUCTION APPOINTMENTS

BULLETIN No. 49

This bulletin is circulated to all members of the Institution monthly as near as possible to the first of the month. Firms or organisations wishing to insert notices in the bulletin should communicate with the Secretary at 10, Chesterfield Street, London, W.1.

The last date for receiving material for insertion in the following month's bulletin is the 20th of each month.

The fee for insertion of particulars regarding each appointment is £3 3s. (up to 100 words), and over 100 words £5 5s. No charge is made to firms affiliated to the Institution, Technical Colleges, Universities and similar organisations.

Advertisers are advised that better response is likely if, in addition to essential qualifications, the following information is given:-
(*a*) Location of appointment; (*b*) Status in the organisation and scope of promotion; (*c*) Salary range and age range.

Advertisers are asked to advise the Institution when vacant appointments are filled. The Institution reserves the right to refuse or withdraw any announcement and also to make any alteration in the wording to ensure conformity with Institution standards.

Members interested in the following appointments should make application in accordance with the terms of notice. No correspondence can be undertaken by the Secretary other than the forwarding of replies to Box Nos.

Chief Jig and Tool Designer. Sir W. G. Armstrong Whitworth Aircraft, Limited, Baginton, Nr. Coventry, wish to appoint a Chief Jig and Tool Designer. Candidates must be over 30 years of age, and have completed a recognised engineering apprenticeship or similar course of training. Minimum technical qualification H.N.C. Airframe experience including interchangeability media advantageous. This is a senior staff appointment with permanency, excellent prospects and conditions and an attractive pension scheme. Write, or call, with full particulars to: the Personnel Manager.

Work Study Engineers. Competent trained men required by go-ahead Midland light engineering Company of international reputation who are rapidly expanding activities of Work Study Departments. Positions offered are progressive and good future prospects await the right men. Applicants must state fully, qualifications, experience, age and salary required to: Box No. 902, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Controller required by firm of engineers in West Midlands. Applicants should be experienced with small batch quantities of medium/heavy products. Good salary and working conditions. Give full details of present and past experience and qualifications in confidence to: Box No. 903, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Engineer conversant with modern methods capable of controlling planning and ratefixing of a medium/heavy firm of engineers. Good salary and working conditions. West Midlands area. Applications should give full details of experience and qualifications in confidence to: Box No. 904, I.Prod.E., 10, Chesterfield Street, London, W.1.

Chief Estimator required by medium/heavy engineering firm in West Midlands. Applicants must have had extensive experience in similar duties and be fully qualified engineers. Good salary and working conditions. State full particulars of experience and qualifications to: Box No. 905, I.Prod.E., 10, Chesterfield Street, London, W.1.

Deputy Toolroom Superintendent. Hoover (Electric Motors), Limited, Cambuslang, Lanarkshire, have vacancy for Deputy Toolroom Superintendent. Applicants must have sound practical and administrative experience suitable for a large toolroom associated with light engineering. Range of work includes diecasting and progressive lamination tooling. Education of Higher National Certificate standard. Applications, giving full details of qualifications for this position, should be made in writing to: the Employment Officer.

Tooling Draughtsmen—experienced in Tooling Layouts required for London Office (Albert Embankment) of B.S.A. Tools, Limited, Birmingham, for the following, design of Cam layouts and tooling equipment for single-spindle automatics and design for tooling equipment for multi-spindle automatics. Applicants should possess sound practical training, preferably in the automatic machine tool field. 5-day week. Pension scheme, canteen facilities. Interviews in London if required. Apply in first instance, stating full particulars, age and salary required, to: Personnel Manager, B.S.A. Tools, Limited, Kitts Green, Birmingham.

Junior and Detail Draughtsmen required on tooling and engineering projects. Good opportunities for advancement. Normal salary rates. Apply in writing in first instance to: General Manager, Minimax, Limited, Staines Road, Feltham.

Time and Motion Study Vacancies. Required by light constructional engineering and window manufacturing works in Essex, men with sound training and varying experience in Time and Motion Study work. Experience in engineering preferable but not essential. 5-day week, staff pension scheme. Apply, giving full particulars, including age, experience and salary required, to: Staff Employment Officer, Crittall Manufacturing Co., Ltd., Braintree, Essex.

Marconi's have the following vacancies at their Basildon New Town Works. Applicants should have O.N.C. at least, and served apprenticeship, preferably in tool room:

Machining Methods Planners: Should have had 3 years on Tool Design; able to determine economic operation sequences from piece part drawings and outline necessary tooling.

Assembly Methods Planners: Knowledge of general machine shop and electronic assembly shop methods, bench layouts, capable of own draughtsmanship.

Tool Designers: Should have had 2 years on tool design, be familiar with modern tooling methods, able to produce efficient designs from verbal instructions.

Tool Draughtsmen: Must have had Drawing Office experience, be familiar with tooling and assembly methods, able to make sound designs from sketches supplied by senior. Houses available to rent. Write: Marconi's Wireless Telegraph Co., Ltd., Basildon, Essex.

Production Engineers are required by a Company supplying special purpose machine tools. Sales experience is not so important as sound technical knowledge and experience in large scale machine shop production. A senior man is required for Scotland and a junior for the London office. Full particulars to: Box No. 906, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Controller. A general engineering works in Yorkshire is appointing a Senior Executive to take charge of the Production Control Department with responsibility for Programming, Loading, Progressing and Stock Control. Applicants should be between 30 and 40 years of age; preference will be given to those with an Engineering Degree. They should have had at least five years works organisation experience, and specialised training may be given. A four figure salary is envisaged for this appointment. Applications, which will be treated in strict confidence, to: Box. No. 907, I.Prod.E., 10, Chesterfield Street, London, W.1.

Estimator. Engineering firm in West London require the services of first class estimator with good experience of machine shop estimating. Experience with stainless steel and/or sheet metal work is also desirable. The post offers good prospects for energetic man who is prepared to work

hard and produce results. Salary in accordance with qualifications. Reply to: Box No. 908, I.Prod.E., 10, Chesterfield Street, London, W.1.

Civil Engineer, Mechanical Engineer, Production Engineer & Works Manager. An important organisation with interests throughout the British Isles and Commonwealth requires the services of a Civil Engineer, Mechanical Engineer, Production Engineer and Works Manager. In each appointment proper qualifications and adequate executive experience are necessary. Age not over 45. Remuneration proposed is on the highest scale and there are good prospects. Full details of qualifications, posts held and salaries to: Box No. 909, I.Prod.E., 10, Chesterfield Street, London, W.1.

Works Superintendent for dry battery factory in India having considerable engineering experience, thoroughly familiar with latest mass production methods and capable of assuring quality product. Apply by air mail, giving full details of age, qualifications, experience and salary required, to: Estrela Batteries, Limited, Post Box No. 6602, Bombay, 19 (India).

Production Engineer of first class ability required by well known manufacturers of table stationery and catering paperware located 30 miles north of London. Applicant is required to be technically competent on paper conversion plant and printing processes: He should have held a supervisory position on the factory floor and have had practical experience in the operation of modern production and material control systems and methods study. Pension scheme. After 6 months of satisfactory service there will be the prospect of promotion to a more important appointment. Apply, with full details of qualifications, to: Box No. 910, I.Prod.E., 10, Chesterfield Street, London, W.1.

Technical Assistants required for investigational work in connection with radio valve manufacture. Applicants should possess at least Higher National Certificate. 5-day week, modern welfare facilities, staff pension scheme. Write, giving full personal details, including age, qualifications and experience. Box No. 911, I.Prod.E., 10, Chesterfield Street, London, W.1.

Methods Engineer required by well-known cleanery in London. Company carries out high quality dyeing and cleaning, with modern light engineering and process plant. Responsibility for introduction of new methods, layout, work study, incentives and progress. Sound knowledge of production engineering essential. Starting salary approximately £650 p.a. according to experience. Box No. 912, I.Prod.E., 10, Chesterfield Street, London, W.1.

Development Engineer required for mass production precision engineering works in North Midlands. The methods and processes are of varied nature covering in the main, machining grinding, assembly and inspection and the appointment is with a view to introducing new and improved methods on a high precision quality product. Applicants, who should be about 35 years of age, must have had a good technical and practical experience, possess initiative, discernment and have a flair for experimental work and investigation, will be given guidance and every assistance. Some knowledge of electricity desirable. The position is permanent for a suitable applicant who should derive considerable satisfaction and interest from the work. The Company is old established and operates a pension scheme. Reply in confidence, giving full particulars of experience, qualifications, salary required and age. No original testimonials please. Box No. 913, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Engineer required to take charge of work study in medium-sized factory in South London engaged in box making, and to develop this function to the status of Production Engineering. Experience of Work Study essential, but further training will be available from the Production Engineer to the Group of Companies. Preferred age, 25-35. Salary commensurate with ability and experience, but £550 per annum is indicative. Reply in confidence, stating qualifications and experience, to: Box No. 914, I.Prod.E., 10, Chesterfield Street, London, W.1.

Welding Instructor. G. A. Harvey & Co. (London), Limited, require welding instructor for works welding school. Applicants must be capable of practical and theoretical training of apprentices and skilled welders in oxy-acetylene, argon-arc and electric welding to the highest standards in the industry. Apply, stating age, experience and salary required, to: the Labour Office, Woolwich Road, Charlton, London, S.E.7.

Senior Jig and Tool Draughtsmen required for Oil Engine Work, modern factory in Midlands. Applicants should have had minimum 5 years' jig and tool experience. Salary up to £725 p.a. Write to: Box No. 915, I.Prod.E., 10, Chesterfield Street, London, W.1.

Works Manager. The Tilley Lamp Company, Limited, Brent Works, 114, Colindale Avenue, Colindale, London, N.W.9., manufacturers of pressure paraffin lamps and heaters, invite applications for the position of Works Manager, age 35 to 50. The man appointed will have complete control of an up-to-date and well equipped, rapidly expanding, light engineering factory, employing approximately 400 persons. Candidates must have high qualifications and experience as Works Manager, with a thorough practical knowledge of planning, tool design, automatic lathe and press shop production, together with assembly and finishing methods. The applicant must be able to lead, and foster good staff relations and consider the post a permanency, which will carry a salary commensurate with the responsibility involved. Applications, giving full details of education, experience and positions held, will be treated in the strictest confidence, and should be addressed to the Director of Production, address as above.

Time Study Engineers required, preferably with light engineering background. Would consider trainees with suitable qualifications. Permanent positions with chance of promotion. Apply, giving full details of experience, age, salary requirements, to: The Secretary, Mettoy Co., Ltd., Fforestfach Trading Estate, Swansea.

Engineer. Production Engineering Research Association has vacancy for an engineer in the Technical Enquiry Section which deals with a wide variety of production problems for member-firms. Good opportunities for advancement for man with initiative. Superannuation under F.S.S.U. Full details of age, experience, qualifications, salary required, etc., to: Secretary, PERA, Melton Mowbray.

Methods & Time Study Engineer is required to take charge of important sub-sections in a well-known light engineering company in West Middlesex. Applicants must be of H.N.C. standard and have a thorough knowledge of work study and synthetic procedures as applied to modern machine and assembly shops involving large batch and semi mass production techniques. Age, early thirties. Apply in first instance, stating qualifications, experience and age, to: the Personnel Manager, Box No. 916, I.Prod.E., 10, Chesterfield Street, London, W.1.

Senior Methods Engineers required by The English Electric Co., Ltd., Luton, for work on medium quantity production. Applicants must be fully experienced on one of the following types of work: (a) general machine shop, (b) assembly, (c) electronic assembly. The posts bear the responsibility for reviewing designs for ease of production, methods planning, estimating and proving methods on production, and call for a high standard of ability and initiative. These are senior appointments carrying appropriate salaries and housing assistance will be available to the successful applicants from the Greater London area. Applications, stating age, experience and qualifications, to: Dept. C.P.S., 336/7, Strand, London, W.C.2., quoting ref. 1360A.

Engineers. Applications are invited from engineers, aged approximately 25/30 years, who are looking for a position of advancement, and who have had experience in one of the following categories: (a) Machine Tool Construction and Maintenance, (b) High Precision Production and Inspection, (c) Methods Engineering and Jig and Tool Design. Applicants must hold National or Higher National Certificates or equivalent qualifications. The Works are situated in South West England, and are expanding. Salary will be based on experience and qualifications. Please give full details of age, experience, etc. Box No. 917, I.Prod.E., 10, Chesterfield Street, London, W.1.

Draughtsmen required. Experience of Jig and Tool design is essential and knowledge of large scale production methods desirable. Permanent and progressive positions with excellent conditions at modern factory in Walsall area. 37½-hour week. Salary will be generous to right type of applicants. Details of experience should be given to: Box No. 918, I.Prod.E., 10, Chesterfield Street, London, W.1.

Designer-Draughtsmen, qualified, required for interesting work on all types of weighing machinery. Desirable applicants will possess H.N.C. or equivalent, have served a General Engineering Apprenticeship, be progressive, and capable of enhancing our design prestige with the future generation. The positions are permanent, with good prospects, and pension scheme. Apply by letter, stating age (25-40) and salary required, to: Vandome & Hart, Limited, Wenlock Road, London, N.1.

Process Planning/Time Study Engineer. Applications are invited for the position of Process Planner in a new factory being set up in Team Valley Estate, Gateshead, for the manufacture of Rocker Shovels, and Filtration Equipment. The appointment is for a post not previously existing, and offers scope for advancement for a man having a sound experience in process planning and rate-fixing on machining and assembly. The commencing salary will be upwards of £750 according to experience and ability. Apply in writing to: The Works Manager, Eimco (G.B.), Limited, Barras Garth Road, Leeds, 12.

Planning Engineers required by Hunting Percival Aircraft, Limited. Experience in manufacture, installation and production planning of metal airframe components essential. Good welfare facilities, including staff pension scheme. Applications, stating age, salary required, and full details of experience, to: Personnel Manager, Hunting Percival Aircraft, Limited, Luton Airport, Bedfordshire.

Senior Production Staff. Graduates of British Universities who are, or have been, employed by one of the well-known firms of industrial consultants are invited to apply for a position on the senior production staff of a large engineering company situated in the Midlands. The salary will be of the order of £1,500 to £2,500 depending on qualifications, and there are very good opportunities for advancement for the right man to the position of General Manager. Age limits, 24 to 40. There is a good pension scheme. Replies will be treated in strict confidence and should give full details of education, qualifications and experience, to: Box No. 919, I.Prod.E., 10, Chesterfield Street, London, W.1.

Methods Engineer. Light/medium engineering works has vacancies for trained Methods Engineers. Applicants should preferably have had tool room and/or jig and tool drawing office experience. Knowledge of capstan work, milling, drilling and flow line assembly an advantage. Position is permanent and pensionable, with scope for advancement for energetic men with up-to-date and progressive ideas. Apply, in confidence, to: Personnel Manager, Monitor Engineering and Oil Appliances, Limited, Iron Lane, Stechford, Birmingham, 33.

Methods Engineer, aged 28-40, required by progressive and expanding light engineering company (not aircraft) in Gloucestershire. The man required should have a sound engineering background and experience in jig and tool design as applied to the machining and assembly of precision units. A knowledge of estimating would be an advantage. Applicants should state actual age and give particulars of education and previous position held. Box 2P, J.9841, A. K. Advg., Ltd., 212a, Shaftesbury Avenue, London, W.C.2.

Senior Jig and Tool Draughtsmen. International Harvester Company, manufacturers of agricultural machinery and equipment, Wheatley Hall Road, Doncaster, require Senior Jig and Tool Draughtsmen, age, 25-40 years: men with H.N.C. preferred. Write, stating age, experience and salary required.

Senior Production Engineer required by large light engineering manufacturing company in Sydney, Australia. Preference will be given to man with wide production engineering responsibility, practical experience including tool design, and with education to H.N.C. standard. Age 35 to 40. Starting salary up to A£1,600. The Company is well established and operates a non-contributory pension plan. This is an excellent opportunity for an energetic man with the right education and experience to make a progressive career in Australia. Selected individuals will be interviewed in London. Apply: Box No. 920, I.Prod.E., 10, Chesterfield Street, London, W.1.

Work Study. A vacancy occurs for young man to assist in introduction of work study into large factory in Slough area. Applicants, age 22/28 years, should have considerable experience of method study and work measurement techniques. A knowledge of compiling synthetics would be an added advantage. Salary according to experience but not less than £600 per annum. Write in confidence, stating age, education, experience and present salary, to: Personnel Manager, Box No. 921, I.Prod.E., 10, Chesterfield Street, London, W.1.

Manager required in Macclesfield for sheet metal department. Applicants must have a good education and a knowledge of modern jigs and tools used in the manufacture of tins and similar articles. The successful applicant will be required to develop the department, including establishing a sales organisation and policy for the marketing of the products. Minimum commencing salary will be about £700, but the upper limit will depend entirely on the results achieved. Applications should be made to Hovis, Limited, Macclesfield, and interviews can be arranged either in Macclesfield or in London.

Methods Officer. Required to work as part of an Organisation and Methods team, attached to the Central Accounts Office, in a public company operating several factories in the manufacture of a wide range of products, and under the leadership of a Cost and Works Accountant. Duties will cover incentive bonus schemes, standard cost revision and similar matters. Must be fully conversant with time and motion study and modern production methods. Position based on London, but frequent travelling involved. Salary, £850 per annum. Box No. 922, I.Prod.E., 10, Chesterfield Street, London, W.1.

Senior Draughtsman required immediately. Must be fully conversant with mechanical handling equipment and associated steel structures. Good working conditions, 5-day week, canteen, etc. Excellent opportunity for suitable applicant. Apply, giving full particulars of previous experience, stating salary required, to: August's Limited, Halifax.

PETERBOROUGH **7.15 p.m. OCTOBER 7th**
The Dujon Ballroom.
"Plant Maintenance and Productivity" by R. A. Rogers, B.Sc., A.M.I.E.E. (Hoover, Ltd.).
Joint meeting at invitation of the Peterborough Branch of the Institute of Plant Engineers. (Members only.)

PRESTON **7.15 p.m. OCTOBER 13th**
The Crown Hotel, Market Place, Blackburn.
"The Value of Work Study to Industry" by W. H. Hodgetts, M.I.Prod.E.

READING **7.30 p.m. OCTOBER 7th**
The Great Western Hotel, Reading.
"The Influence of the Production Engineer on Productivity" by Prof. J. V. Connolly, B.E., F.R.Ae.S., M.I.Prod.E.

ROCHESTER **7.30 p.m. OCTOBER 14th**
The Sun Hotel, Chatham.
"Design for Arc Welding" by S. M. Reisser, B.Sc. (Eng.), A.M.I.C.E., M.I.Struct.E. (Murex Welding Processes, Ltd.).

SHEFFIELD **7.0 p.m. for 7.30 p.m. OCTOBER 11th**
The Grand Hotel, Sheffield.
Annual Dinner.

SHEFFIELD GRADUATE **6.30 p.m. OCTOBER 25th**
The Royal Victoria Station Hotel.
"Shell Moulding" by D. N. Buttrey, M.Sc., A.R.I.C., A.P.I.
Lecture illustrated by 35 mm. Film Strip.

SHREWSBURY **7.30 p.m. OCTOBER 27th**
The Oakengates Technical College, Oakengates.
"Colour as an Aid to Production" by Miss Raine.

SOUTHERN **7.15 p.m. OCTOBER 7th**
The Polygon Hotel, Southampton.
"Surface Finish" by J. Halling, B.Sc. (Eng.).

SOUTHERN **7.0 p.m. OCTOBER 13th**
The Southampton University.
"Titanium" by P. L. Teed.
Meeting arranged by the Southampton Branch of the Royal Aeronautical Society.

SOUTH ESSEX **7.30 p.m. OCTOBER 13th**
The Mid-Essex Technical College, Chelmsford.
"New Developments in Work Study" by A. W. H. Walker, Director of Studies at the Work Study School. (College of Aeronautics, Cranfield.)

SOUTH WALES & MONMOUTHSHIRE **7.0 p.m. OCTOBER 28th**
The South Wales Institute of Engineers, Park Place, Cardiff.
"High Speed Presswork"—(Illustrated by lantern slides). By J. A. Grainger, A.M.I.Mech.E., A.M.I.Prod.E.

STOKE-ON-TRENT **7.15 p.m. OCTOBER 18th**
The Hanley Town Hall, Hanley, Stoke-on-Trent.
"Engineering Potentialities of Spheroidal Graphite Cast Iron with special reference to the machine tool and general Engineering Industries" by A. B. Everest, Ph.D., F.I.M.

TEES-SIDE **7.0 p.m. OCTOBER 27th**
The Cleveland Scientific and Technical Institution, Middlesbrough.
"Machines and Men" by Prof. Aubrey F. Burstall, D.Sc., Ph.D., M.I.Mech.E. (Prof. of Mechanical Engineering and Director of the Stephenson Engineering laboratories at the University of Durham).

WESTERN GRADUATE **7.30 p.m. OCTOBER 4th**
The Grand Hotel, Bristol.
"Work Study" by G. R. Burn, A.M.I.Mech.E., A.M.I.Prod.E.

WEST WALES **7.30 p.m. OCTOBER 1st**
The Central Library, Alexandra Road, Swansea.
"Economics of Production" by E. G. Brisch, M.I.Mech.E., M.I.Prod.E.

WOLVERHAMPTON GRADUATE **7.30 p.m. OCTOBER 20th**
The Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
"Safety in the Factory" by E. W. Huddy, H.M. District Inspector of Factories.

WOLVERHAMPTON GRADUATE **8.0 p.m. to 1.0 a.m. OCTOBER 22nd**
Wulfruna Hall, Wolverhampton.
Graduate Dance.

WORCESTER **7.30 p.m. OCTOBER 27th**
The Cadena Cafe, Worcester.
Film Show, entitled "High Speed Forging" introduced by R. Howes of Messrs. Buck and Hickman.

YORKSHIRE GRADUATE **3.0 p.m. OCTOBER 9th**
Works visit to the Criminal Investigation Department, West Riding Constabulary, Wakefield.
Rendezvous: C.I.D. Block, Wakefield.

NOVEMBER 1st - 9th, 1954.

COVENTRY GRADUATE **7.30 p.m. NOVEMBER 9th**
The Craven Arms Hotel, High Street, Coventry.
"Should Production Control Design"—with special reference to automobile engineering. Debate. Joint meeting with the Institution of Mechanical Engineers.

DONCASTER **7.0 p.m. NOVEMBER 9th**
The Danum Hotel, Doncaster.
"Motion Economy" by Miss A. G. Shaw, M.A., M.I.Prod.E.

GLASGOW **7.30 p.m. NOVEMBER 4th**
The Institute of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2.
Open Discussion Night.

GLOUCESTER & DISTRICT **7.15 p.m. NOVEMBER 4th**
The Bell Hotel, Gloucester.
"Productivity" by F. L. Daniels, M.I.Prod.E., M.I.Mech.E., F.G.S.
Joint meeting with the Western Section of the Plastics Institute.

HALIFAX **7.15 p.m. NOVEMBER 2nd**
The White Swan Hotel, Halifax.
"The Shell Moulding Process" by D. N. Buttrey, M.Sc., A.R.I.C., A.P.I.

HALIFAX GRADUATE **7.30 p.m. NOVEMBER 8th**
The Whiteleys Cafe, Westgate, Huddersfield.
"The Construction and Development of Artificial Satellites" by M. S. Wright (Yorkshire Secretary, British Interplanetary Society).

MANCHESTER GRADUATE **7.15 p.m. NOVEMBER 2nd**
Reynolds Hall, College of Technology, Sackville Street, Manchester.
"Recent Advances in Plastics—Polytetrafluorethylene" by E. M. Elliott, A.M.I.Prod.E. (Imperial Chemical Industries, Ltd., Plastics Division).

NOTTINGHAM **7.0 p.m. NOVEMBER 2nd**
Welbeck Hotel, Milton Street, Nottingham.
"Costing and Measurement of Productivity" by W. Coutts Donald, C.A., F.C.W.A. Joint meeting with Institute of Cost & Works Accountants.

OXFORD **NOVEMBER 9th**
The Town Hall, Oxford.
"Form in Design and its Influence upon Productivity" by J. Beresford-Evans, M.S.I.A.

PETERBOROUGH **7.30 p.m. NOVEMBER 3rd**
The Campbell Hotel, Bridge Street, Peterborough.
"Motion and Time Study" by Miss Anne G. Shaw, M.A., M.I.Prod.E.

READING **7.30 p.m. NOVEMBER 4th**
Petters, Ltd., Causeway Works, Staines, Middlesex.
"Recent Developments in Work Study" by N. A. Dudley, B.Sc. Econ. (Hons.), M.I.Prod.E.

SHEFFIELD **6.30 p.m. NOVEMBER 8th**
The Grand Hotel, Sheffield.
"Boron Steels" by R. Wilcock.

WOLVERHAMPTON **7.15 p.m. NOVEMBER 3rd**
Dudley & Staffordshire Technical College, Dudley.
"High Frequency Heating and Induction Hardening" by Dr. R. H. Barfield, D.Sc., M.I.E.E.

YORKSHIRE **7.0 p.m. NOVEMBER 8th**
The Hotel Metropole, Leeds.
"Men and Machines" by J. E. Hill, M.I.Mech.E., M.I.Prod.E.

YORKSHIRE GRADUATE **2.30 p.m. NOVEMBER 6th**
The Great Northern Hotel, Leeds.
"Education and the Production Engineer" by R. Shilton, A.M.I.Prod.E., M.I.Mech.E.

MEETINGS

Visitors tickets may be obtained from Section Honorary Secretaries

OCTOBER 1954

BIRMINGHAM **7.0 p.m. OCTOBER 20th**
The James Watt Memorial Institute, Great Charles Street, Birmingham, 3. "A Job Evaluation System and its Influence on Productivity" by R. N. Marland, B.Sc., M.I.Prod.E., A.M.I.Mech.E.

BIRMINGHAM **6.30 p.m. OCTOBER 1st**
The Botanical Gardens, Edgbaston, Birmingham.
Annual Dinner Dance.

BIRMINGHAM GRADUATE **7.0 p.m. OCTOBER 12th**
The James Watt Memorial Institute, Great Charles Street, Birmingham, 3.
"Lighting and Productivity" by J. F. Roper, A.M.I.E.E.

BIRMINGHAM GRADUATE **OCTOBER 13th**
Works visit to Jury Holloware, Ltd.

COVENTRY **7.30 p.m. OCTOBER 15th**
The Matrix Hall, Fletchamstead Highway, Coventry.
Dinner and Dance.

COVENTRY **7.0 p.m. OCTOBER 19th**
The Craven Arms, High Street, Coventry.
"The Application of Hydraulic Power as an Aid to Productivity versus Electronics" by F. B. Levetus and R. H. Kelsall.

COVENTRY GRADUATE **7.15 p.m. OCTOBER 12th**
The Hare and Squirrel Hotel, Cow Lane, Coventry.
"Some Interesting Set-ups on Modern Machine Tools" by R. C. Fenton, M.I.Prod.E.

CORNWALL **7.15 p.m. OCTOBER 20th**
The Cornwall Technical College, Trevenson, Pool, Redruth, Cornwall. Film Evening. A Programme of Sound Films on Production Engineering subjects, selected and presented by members of the Committee.

DERBY **7.0 p.m. OCTOBER 18th**
The College of Art, Green Lane, Derby.
"The Use of the Autocollimator in Engineering Metrology" by C. C. Taylerson, M.B.E.

DONCASTER **7.0 p.m. OCTOBER 12th**
The Danum Hotel, Doncaster.
"Production Methods in Railway Workshops" by T. B. Maddison, A.M.I.Prod.E.

DUNDEE **7.30 p.m. OCTOBER 27th**
The School of Economics, Dundee.
"The Motion Study Aspect of Work Study" by Miss Anne Shaw, M.A., M.I.Prod.E. Sponsored by the Dundee Productivity Council.

EASTERN COUNTIES **7.30 p.m. OCTOBER 15th**
Davey, Paxman & Co., Ltd., Britannia Works Canteen, Colchester.
"Process Development of Shell Moulding" by A. Woods.
Combined Meeting with Colchester Engineering Society.

GLASGOW **7.30 p.m. OCTOBER 21st**
The Institute of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2.
"Ball and Roller Bearing Manufacture and Application" by C. S. Clarke.

EAST & WEST RIDINGS REGIONAL MEETING
7.15 p.m. OCTOBER 4th
The George Hotel, Huddersfield.
"Industrial Uses of 'Terylene' Polyester Fibre"—Regional Meeting. By D. N. Marvin, A.R.I.C., A.T.I., arranged by the Halifax Section.

LEICESTER **7.0 p.m. OCTOBER 14th**
Balmoral Room, Bell Hotel, Leicester.
"On Being a Production Engineer" by J. C. Routledge, M.I.Prod.E., Chairman's Address.

LINCOLN **7.0 p.m. for 7.30 p.m. OCTOBER 21st**
The Ruston Club, Unity Square, Lincoln.
Dinner and Dance.

LONDON **7.0 p.m. OCTOBER 21st**
The Royal Empire Society, Northumberland Avenue (Craven Street Entrance), London, W.C.2.
"A Production Engineer reviews Welding Shop Organisation and the relationship of the Welding Shop to other Manufacturing Departments" by F. G. C. Sandiford, A.M.I.Mech.E., A.F.R.Ae.S., M.I.Prod.E.
Joint meeting with The Institute of Welding.

LONDON GRADUATE **7.15 p.m. OCTOBER 19th**
The Institution of Production Engineers, 10, Chesterfield Street, London, W.1.
"Ultrasonic Machining of Hard Materials" by C. F. Brockelsby, A.R.C.S., B.Sc., A.M.I.E.E.

LUTON **7.15 p.m. OCTOBER 26th**
The Small Assembly Room, Town Hall, Luton.
"High Permeability Steel Castings for the Electrical Industry" by J. F. Hinsley, F.I.M.
Joint meeting with Eastern Branch Institution of Mechanical Engineers.

LUTON GRADUATE **10.15 a.m. OCTOBER 30th**
Visit to The De Havilland Engine Co., Ltd. (Works), Leavesden, Watford, Hertfordshire.

MANCHESTER **7.15 p.m. OCTOBER 18th**
Reynolds Hall (Room C.3), College of Technology, Sackville Street, Manchester, 1.
"Tracer Control of Machine Tools" by J. Lund, M.I.Prod.E.

LINCOLN **7.30 p.m. OCTOBER 20th**
Scunthorpe.
"The Institution and You" by J. E. Hill, M.I.Mech.E., M.I.Prod.E.

MANCHESTER GRADUATE **7.15 p.m. OCTOBER 5th**
Reynolds Hall, College of Technology, Sackville Street, Manchester.
"Rust, its Prevention and Removal" by F. S. Bricknell (Technical Manager, Jenolite, Ltd.).

NORTH EASTERN **7.0 p.m. OCTOBER 18th**
The Neville Hall, Newcastle-upon-Tyne.
"Shell Moulding for the Production Engineer" by A. Woods.

NORTH EASTERN GRADUATE
7.0 p.m. OCTOBER 8th
Roadway House, 8, Oxford Street, Newcastle-upon-Tyne.
"Nickel Plating and Metal Finishing" by L. F. Prior.

NORTH EASTERN GRADUATE
10.0 a.m. OCTOBER 16th
Visit to the Mechanical Plating Plant of A. Reyrolle & Co., Ltd.

NORWICH **7.30 p.m. OCTOBER 20th**
The Esplanade Restaurant, Lowestoft.
"Arc Welding in Engineering and Ship Work" by Mr. H. Roscoe and Mr. R. A. Peacock.
The Lecture will be fully illustrated with slides.

NORTHERN IRELAND **7.30 p.m. OCTOBER 14th**
The Kensington Hotel, Belfast.
A short opening talk by the Section Chairman, followed by a film show based upon the life of Lord Kelvin.

NOTTINGHAM **7.0 p.m. OCTOBER 6th**
Victoria Station Hotel, Milton Street, Nottingham.
"Impressions of Production Methods in U.S.A."
By selected members from Productivity teams.

OXFORD **7.15 p.m. OCTOBER 4th**
The Town Hall, Oxford.
"We Too Can Prosper".
By Graham Hutton, O.B.E. Meeting in association with the Oxford Productivity Committee.

PETERBOROUGH **7.30 p.m. OCTOBER 5th**
The Campbell Hotel, Bridge Street, Peterborough.
"Production of Domestic Appliances" by H. F. Adams, M.I.Prod.E. (Works Manager, The Hotpoint Electric Appliance Co., Ltd.).
Visitors will be welcome.

EDUCATIONAL APPOINTMENTS

Coventry Technical, College, Coventry
Lecturer in Mechanical Engineering Department, required January 1955. Candidates should hold Hons. Degree in Engineering, be able to offer Mechanics of Fluids and Thermodynamics to Final Degree Standard and have good industrial and teaching experience. Salary, Burnham Technical Scale (£965 x £25 - £1,065). Application forms from Director of Education, Council House, Coventry.

Acton Technical College, High Street, Acton, W.3.
Lecturer in the Department of Management & Production Engineering. Applications are invited for a Lecturer in the Department of Management and Production Engineering required to carry responsibility for developing with industry collaborative teaching in production engineering, relating its technical aspects to its social aspects. This involves the development of practical machine shop work, and probably the teaching of Higher National Certificate subjects such as Press Tools, Plastics Technology, Jig and Tool Design, "Work Study", or on topics such as the human factors in the design of machine controls. Qualifications should include a degree (or its equivalent) in a branch of engineering or in natural science, together with industrial experience. Salary in accordance with Burnham (Technical) Report, 1954. Application forms (stamped addressed envelope) from the Principal, to whom forms should be returned by Monday, 18th October, 1954.